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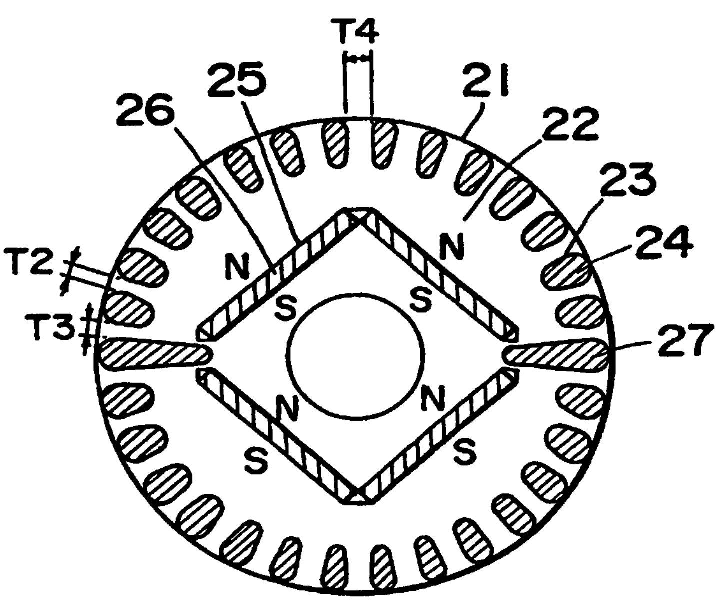
(54) Title: PERMANENT MAGNET SYNCHRONOUS MOTOR



(57) Abstract: A synchronous motor includes a stator, a rotor and permanent magnets. The rotor includes a rotor iron core and rotatable relative to the stator, a plurality of conductor bars accommodated within corresponding slots in the rotor iron core. The conductor bars have their opposite ends shortcircuited by respective shortcircuit rings to form a starter squirrel cage conductor. The rotor also have a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars, in which hole permanent magnets are embedded.

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DESCRIPTION

Permanent Magnet Synchronous Motor

Technical Field

The present invention generally relates to a permanent magnet synchronous motor and, more particularly, to the synchronous motor generally used in a motor-driven compressor in a refrigerating system or an air conditioning system or any other industrially utilized electric appliance.

Background Art

A self-starting permanent magnet synchronous motor operates as an inductor motor at the time of starting thereof owing to a starter squirrel cage conductor and as a synchronous motor as rotating magnetic poles created by the permanent magnets are entrained by a rotating magnetic field formed by a stator winding and moving angularly at a synchronous speed upon arrival of the rotor at a speed approaching the synchronous speed. This synchronous motor has an excellent constant speed operating performance and an excellent high efficiency. In particular, various improvement have hitherto been made to a rotor structure of the synchronous motor.

For example, the Japanese Patent Publications No. 59-23179 and No. 63-20105 discloses the prior art rotor structure for the self-starting permanent magnet synchronous motor.

Fig. 6 illustrates the prior art rotor disclosed in the Japanese Patent Publication No. 59-23179. Referring to Fig. 6, reference numeral 1 represents a rotor, and reference numeral 2 represents a rotor iron core having a plurality of slots 3 defined therein adjacent an outer periphery thereof. Conductor bars 4 are disposed within those slots 3 and have their opposite ends shortcircuited by respective shortcircuit rings to thereby form a starter

squirrel cage conductor. The shortcircuit rings (not shown) are made of an annular electroconductive material disposed on axially opposite ends of the rotor iron core and are connected with the conductor bars 4. A plurality of magnet retaining holes 5 are provided on an inner side of the conductor bars 4, with corresponding permanent magnets 6 embedded therein. Reference numeral 7 represents magnetic flux shortcircuit preventive slits that are spaced such a small distance P from the magnet retaining holes 5 that magnetic saturation can take place between the magnet retaining holes 5 and the slits 7 to thereby prevent the magnetic fluxes emanating from the permanent magnets from being shortcircuited between the different magnetic poles.

Fig. 58 illustrates a longitudinal sectional view of the rotor used in the prior art self-starting synchronous motor disclosed in the Japanese Patent Publication No. 63-20105 and Fig. 59 illustrates a cross-sectional view taken along the line A-A' in Fig. 58. Referring to Figs. 58 and 59, reference numeral 11 represents a rotor, and reference numeral 12 represents a rotor iron core made up of a laminate of electromagnetic steel plates. Reference numeral 13 represents conductor bars having their opposite ends connected with respective shortcircuit rings 14 to thereby form a starter squirrel cage conductor. Reference numeral 15 represents permanent magnets embedded in the rotor iron core to form four rotor magnetic poles. Reference numeral 16 represents magnetic flux shortcircuit preventive slits each operable to prevent the magnetic fluxed between the neighboring permanent magnets of the different polarities from being shortcircuited. Reference numeral 17 represents an end plate disposed on each of axially opposite ends of the rotor iron core 2 by means of bolts to avoid any possible separation of the permanent magnets 5 from the rotor iron core 2.

When the prior art permanent magnet motor of the type provided with the cage conductor is to be used. since the conductor bars and the

permanent magnets are employed as rotatory drive elements, if the conductor bars and the permanent magnets are incorrectly positioned relative to each other, a force generated from the conductor bars and a force generated by the permanent magnets will be counteracted with each other and, therefore, no efficient rotatory drive will be achieved. Also, the permanent magnet motor provided with such a cage conductor requires a complicated and increased number of manufacturing steps since the permanent magnets and the conductor bars are provided in the rotor.

In view of the foregoing, the present invention is intended to solve those problems inherent in the prior art permanent magnet synchronous motor and is to increase the efficiency and simplify the manufacture of the synchronous motor of the type employing the permanent magnets.

Disclosure Of Invention

To this end, the present invention according to a first aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars accommodated within corresponding slots defined in an outer peripheral portion of the rotor iron core, said conductor bars having their opposite ends shortcircuited by respective shortcircuit rings to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars; and permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles. In this synchronous motor, the neighboring members of the slots are spaced a distance which is referred to as a slot interval, the slot interval at a location adjacent one end of rotor magnetic poles being smaller than the slot interval at

a location adjacent a center point of the rotor magnetic poles.

According to the first aspect of the present invention, the magnetic fluxes emanating from the permanent magnets will hardly leak to the outer peripheral surface of the rotor at a position adjacent opposite ends of the rotor magnetic poles and, instead leak to the outer peripheral surface of the rotor at a position adjacent a center point of the rotor magnetic poles. For this reason, the pattern of distribution of the magnetic fluxes in an air gap between the stator and the rotor represents a generally trapezoidal or sinusoidal waveform such that as compared with the rectangular waveform, the amount of change of the magnetic fluxes per unitary time increases and, therefore, the voltage induced across the winding of the stator can be increased to thereby intensify the rotor magnetic poles. Accordingly, in the practice of the present invention, to secure the required induced voltage, neither is the volume of the permanent magnets increased, nor the permanent magnets having a high residual magnetic flux density are required such as required in the prior art, thus making it possible to provide a high-performance and inexpensive self-starting synchronous motor having a required out-of-step torque and a high efficiency.

If the slot interval at a location spaced from the center point of the rotor magnetic poles in a direction conforming to a direction of rotation of the rotor is chosen to be greater than the slot interval at a location spaced from the center point of the rotor magnetic poles in a direction counter to the direction of rotation of the rotor, although during a loaded operation the maximum value of a distribution, on the rotor surface, of composite magnetic fluxes of the magnetic fluxes from the winding of the stator and the magnetic fluxes from the permanent magnets is positioned on one side conforming to the direction of rotation rather than the center point of the rotor magnetic poles, since the slot interval of the rotor through which the magnetic fluxes at that position pass is increased, the magnetic saturation at that portion can be prevented.

Accordingly, the magnetic fluxes emanating from the magnets can be sufficiently taken from the rotor and, therefore, the current across the stator winding can be suppressed to thereby increase the efficiency of the motor.

The present invention according to a second aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars accommodated within corresponding slots defined in an outer peripheral portion of the rotor iron core, said conductor bars having their opposite ends shortcircuited by respective shortcircuit rings to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars; and permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles. In this synchronous motor, the slots have a radial length that is smaller at a center point of the rotor magnetic poles, and a distance between one of the slots positioned adjacent one end of the rotor magnetic poles and the magnet retaining holes is smaller than a distance between the slots positioned at other locations of the rotor and the magnet retaining holes.

According to the second aspect of the present invention, the magnetic fluxes emanating from the permanent magnets will hardly leak to the outer peripheral surface of the rotor at a position adjacent opposite ends of the rotor magnetic poles and, instead leak to the outer peripheral surface of the rotor at a position adjacent a center point of the rotor magnetic poles. For this reason, the pattern of distribution of the magnetic fluxes in an air gap between the stator and the rotor represents a generally trapezoidal or sinusoidal waveform such that as compared with the rectangular waveform, the amount of

change of the magnetic fluxes per unitary time increases and, therefore, the voltage induced across the winding of the stator can be increased to thereby intensify the rotor magnetic poles. Accordingly, in the practice of the present invention, to secure the required induced voltage, neither is the volume of the permanent magnets increased, nor the permanent magnets having a high residual magnetic flux density are required such as required in the prior art, thus making it possible to provide a high-performance and inexpensive self-starting synchronous motor having a required out-of-step torque and a high efficiency.

Preferably, the distance between the slots in the rotor iron core and the magnet retaining holes progressively increases from a position adjacent one end of the rotor magnetic poles towards a position adjacent the center point of the rotor magnetic poles.

The present invention according to a third aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having two-pole windings wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core, and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on the inner side of the conductor bars; and permanent magnets embedded within the magnet retaining holes in the rotor and defining two magnetic poles of different polarities. In this synchronous motor, the shortcircuit rings have an inner diameter positioned outside the associated magnet retaining holes, the inner diameter of the shortcircuit rings at a location adjacent one end of the magnetic poles being chosen to be greater

than an inner diametric dimension at a location adjacent the center point of the magnetic poles.

According to this structure, the width of the permanent magnets can be increased and, therefore, with no need to increase the axial length of the permanent magnets, the requires area of surface of the magnetic poles of the permanent magnets can be secured. Accordingly, there is no need to laminate thickness of the rotor iron core, thereby decreasing the cost.

The inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted may lie outside the magnet retaining holes in the rotor iron core, in which case the inner diametric dimension of one of the shortcircuit rings adjacent one end of the magnetic poles is chosen to be greater than the inner diametric dimension thereof adjacent the center point of the magnetic poles, and the inner diametric dimension of the other of the shortcircuit rings lies inwardly of the whole or a part of the magnet retaining holes. In this structure, an end plate made of a non-magnetizable plate is preferably positioned between such other shortcircuit ring and the rotor iron core so as to cover the magnet retaining holes.

This is particularly advantageous in that not only is there no need to increase the laminate thickness of the rotor iron, but also the cross-section of the other shortcircuit ring is increased to reduce the resistance, and therefore, the number of revolution of the motor at the time of a maximum torque can increase during a period the motor subsequent to the start thereof attains a synchronous speed, thereby increasing the starting performance of the motor.

Also preferably, the inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted lies outside the magnet retaining holes in the rotor iron core, and the inner diametric dimension of one of the shortcircuit rings adjacent one end of the magnetic poles is chosen to be greater than the inner diametric dimension thereof adjacent the center point of

the magnetic poles, whereas the inner diametric dimension of the other of the shortcircuit rings lies inwardly of the whole or a part of the magnet retaining holes. In such case, however, one or a plurality of electromagnetic steel plates of the rotor iron core adjacent the other shortcircuit ring is or are not formed with the magnet retaining holes.

The inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted may be of a shape lying along the magnet retaining holes in the rotor iron core.

Where the stator iron core is made up of a stator laminate of electromagnetic steel plates and the rotor iron core is also made up of a rotor laminate of electromagnetic steel plates, the stator laminate has a thickness about equal to that of the rotor laminate.

The present invention in a fourth aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound and also having an inner cylindrical surface; a rotor including a rotor iron core in the form of a rotor laminate of a plurality of electromagnetic steel plates and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor iron core including a magnet retaining portion provided with magnet retaining slots, a magnetic flux shortcircuit preventive portion coupled with the magnet retaining portion and provided with magnetic flux shortcircuit preventive holes communicated with the magnet retaining holes, and a rotor outer end portion coupled with the magnetic flux shortcircuit preventive portion and provided with holes communicated with the magnetic flux shortcircuit preventive holes; and permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles. In this structure, the magnetic flux shortcircuit preventive holes are smaller than the magnet retaining holes such that by allowing the permanent magnets to be held in engagement with outer edges of the magnetic

flux shortcircuit preventive holes, the permanent magnets are axially positioned.

This structure is advantageous in that the axial position of the permanent magnets can be determined relying only on the rotor iron core and, accordingly, the cost required for assemblage and component parts can be reduced.

The present invention in a fifth aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core in the form of a rotor laminate of a plurality of iron plates and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor iron core including a magnet retaining portion provided with magnet retaining slots, and a permanent magnet support portion coupled with the magnet retaining portion and closing the magnet retaining holes; and permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles. The permanent magnets being axially positioned by means of the permanent magnet support portion.

This structure is advantageous in that the axial position of the permanent magnets can be determined relying only on the rotor iron core and, since one ends of the magnet retaining holes can be closed by the rotor iron plate, closure of the magnet retaining hole by means of the end plate secured to the opposite ends of the magnet retaining holes is effective to permit the use of only one end plate to close the opposite ends of the magnet retaining holes.

An outer end of the rotor iron core may be coupled with the permanent magnet support portion and provided with hole positioned axially of the magnet retaining holes. In this case, the magnetic resistance of a magnetic circuit between the N and S poles at the axially opposite ends of the permanent magnets can be increased to reduce the leakage of the magnetic fluxes,

resulting in increase of the motor characteristic.

Preferably, a starter squirrel cage conductor in the rotor iron core may be employed in the synchronous motor according to the fifth aspect of the present invention.

The present invention in a sixth aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars, said magnet retaining holes having a width in a radial direction of the rotor iron core being greater at a location inwardly of an axial direction of the rotor than at a location adjacent one end of the axial direction of the rotor.

According to this structure, even though shrinkage stresses generated as the shortcircuit rings after the aluminum die casting cools while undergoing shrinkage act on the ends of the rotor iron core, the gap between the permanent magnets and the magnet retaining holes can be maintained at a proper value and, therefore, the insertion of the permanent magnets into the magnet retaining holes can easily be attained, thereby securing a high-performance motor characteristics.

Where the width of the magnet retaining holes in the radial direction is smaller at opposite ends of the axial direction of the rotor than at a

location inwardly of the axial direction of the rotor and further comprising an electromagnetic steel plate provided outside one of the opposite ends of the axial direction of the rotor for closing the magnet retaining holes, the use of only one end plate is sufficient and, therefore, the cost required for the end plate and the number of assembling steps can advantageously be reduced.

Also, where the width of the magnet retaining holes in the radial direction is greater at one of opposite ends of the axial direction of the rotor than at a location inwardly of the axial direction of the rotor and wherein the other of the opposite ends of the axial direction of the rotor is not provided with any magnet retaining holes for closing the magnet retaining holes at a location inwardly of the axial direction of the rotor, not only is the use of only one end plate sufficient, but also the number of combinations of the electromagnetic steel plates is minimized to form the rotor iron core, thereby facilitating manufacture of the motor having a high-performance

The present invention in a seventh aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars. The rotor iron core employed is in the form of a laminate of electromagnetic steel plates and including an entwining portion provided adjacent the magnet retaining holes for

lamination of the electromagnetic steel plates, and the magnet retaining holes adjacent the entwining portion has a width in a radial direction thereof which is partially enlarged in a direction towards the entwining portion.

According to this structure, even though when the entwining portion is formed by the use of any known press work, portions of the electromagnetic steel plates adjacent the entwining portion protrude under the influence of press stresses, the gap between the permanent magnets and the magnet retaining holes can be maintained at a proper value to thereby facilitate insertion of the permanent magnets and also to provide a high-performance motor characteristic.

The present invention in an eight aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars. The rotor iron core has conductor bar holes defined therein in an axial direction thereof and positioned inwardly of the magnet retaining holes, and the conductor bar holes are filled up by the aluminum die casting simultaneously with the starter squirrel cage conductor. The conductor bars so filled protrude a distance outwardly from an axial end of the rotor iron core to form respective projections for securement of an end plate. The end plate is made of a non-magnetizable

material and secured fixedly to the end of the rotor iron core.

This structure is effective in that after the starter squirrel cage conductor and the projections for securement of the end plate have been formed simultaneously by the use of the aluminum die casting technique, engaging the projections into the engagement holes in the end plate and staking or crimping respective tips of the projections result in firm connection of the end plate to the end face of the rotor iron core and, therefore, with no need to employ any bolts, the end plate can easily be secured to the end of the rotor iron core. This permits reduction in cost for material and facilitates assemblage of the motor.

The end plate disposed at the axial end of the rotor iron core may be partly or wholly covered by the corresponding shortcircuit ring, in which case a job of connecting the end plate to the end face of the rotor iron core is sufficient at only one side of the rotor iron core.

The end plate covered by the shortcircuit ring may be provided with projections engageable in respective holes in the rotor iron core, so that positioning of the end plate can easily be performed and, also, the possibility can be eliminated which the end plate may displace from the right position under the influence of flow of a high-pressure aluminum melt during the aluminum die casting.

Also, one or a plurality of electromagnetic steel plates at one axial end of the rotor iron core may not be provided with any magnet retaining hole, in which case only one end plate is sufficient at the opposite axial end of the rotor iron core, thereby reducing the cost for material and the number of assembling steps.

In addition, projections may be provided at a location where the electromagnetic steel plates not provided with any magnet retaining holes contact the permanent magnets, so as to protrude towards the permanent

magnets. In this case, the permanent magnets can be axially positioned upon engagement only with the projections and, therefore, the magnetic flux shortcircuit between the different poles of the permanent magnets through the electromagnetic steel plates can be reduced considerably, thereby increasing the performance of the motor.

The present invention in a ninth aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein, one of the shortcircuit rings having an inner periphery formed with recesses; permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars; and an end plate made of a non-magnetizable material and having an outer periphery formed with projections complemental in shape to the recesses in the shortcircuit ring, a peripheral portion of each of the recesses in the shortcircuit ring being axially pressed to deform to thereby secure the end plate to an axial end of the rotor iron core with the projections in the end plate received in the corresponding recesses in the shortcircuit ring.

Thus, after the end plate can be mounted on the shortcircuit rings with the projections aligned with and received in the corresponding recess in the shortcircuit rings, pressing the respective peripheral portions of the recesses in the shortcircuit rings to deform results in fixing of the end plate to the end face

of the rotor iron core, thereby facilitating the fitting of the end plate.

The present invention according to a tenth aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein, one of the shortcircuit rings having an inner periphery formed with recesses; permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars; said magnet retaining holes being of a design allowing the permanent magnets, when embedded therein so as to be butted end-to-end in a generally V-shaped configuration to form a single magnetic pole, and having an air space defined between one end face of the permanent magnet and an inner face of one end of the magnet retaining hole for preventing shortcircuit of magnetic fluxes, a barrier slot for preventing shortcircuit of magnetic fluxes being defined between the magnet retaining holes for accommodating the neighboring permanent magnets of different polarities, a first bridge portion being provided between the magnet retaining hole and the barrier slot so as to sandwich the barrier slot, and a second bridge portion being provided between the neighboring permanent magnets of the same polarity and the corresponding magnet retaining holes, said second bridge portion being narrow at a location adjacent a center of the rotor and large at a location adjacent an outer periphery of the rotor.

This structure is effective not only to avoid shortcircuit of the

magnetic fluxes between the different poles at the end faces of the permanent magnets to thereby increase the motor performance, but also to reduce the shrinkage strain of the rotor iron core outer diameter at the center of the rotor magnetic poles, that have resulted from shrinkage of the shortcircuit rings in a radial direction thereof after the aluminum die casting, to a very small value because of the strength of the bridge portion having been increased. Therefore, the gap size between the stator iron core inner diameter and the rotor iron core outer diameter can be accurately obtained merely by blanking the electromagnetic steel plates for the rotor iron core by the use of any known press work and the outer diameter of the rotor iron core need not be ground, thereby reducing the number of assembling steps.

The present invention according to an eleventh aspect thereof provides a synchronous motor which comprises a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface; a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein, one of the shortcircuit rings having an inner periphery formed with recesses; permanent magnets embedded within the magnet retaining holes at a location on the inner side of the conductor bars to provide two magnetic poles; said rotor iron core increasing from axially opposite ends thereof towards a center point of the length of the rotor to render it to represent a generally oval shape, the permanent magnets being mounted after formation of the starter squirrel cage conductor by means of the aluminum die

casting.

According to this structure, even if the shrinkage strain of the rotor iron core outer diameter in a radial direction increases towards the center of the rotor magnetic poles after the aluminum die casting, the outer diameter of the rotor iron core after shrinkage can be kept to the right round shape and, therefore, the gap size between the stator iron core inner diameter and the rotor iron core outer diameter can be accurately obtained merely by blanking the electromagnetic steel plates for the rotor iron core by the use of any known press work and the outer diameter of the rotor iron core need not be ground, thereby reducing the number of assembling steps. Also, since the aluminum die casting is performed while the permanent magnets and the end plates have not yet been fitted, the job can easily be performed without incurring any defective component parts, thereby increasing the productivity.

Where the permanent magnets are employed in the form of a rare earth magnet, a strong magnetic force can be obtained and both the rotor and the motor itself can advantageously manufactured in a compact size and lightweight.

Brief Description Of Drawings

The present invention will become readily understood from the following description of preferred embodiments thereof made with reference to the accompanying drawings, in which like parts are designated by like reference numerals and in which:

Fig. 1 is a transverse sectional view of a rotor used in a synchronous motor according to a first preferred embodiment of the present invention;

Fig. 2 is a chart showing a pattern of distribution of magnetic flux densities in a gap between a stator and the rotor;

Fig. 3 is a transverse sectional view of the rotor used in the

synchronous motor according to a second preferred embodiment of the present invention;

Fig. 4 is a transverse sectional view of the rotor used in the synchronous motor according to a third preferred embodiment of the present invention;

Fig. 5 is a transverse sectional view of the rotor used in the synchronous motor according to a fourth preferred embodiment of the present invention;

Fig. 6 is a transverse sectional view of the rotor used in the prior art self-starting synchronous motor of a kind utilizing permanent magnets;

Fig. 7 is a chart showing the prior art self-starting synchronous motor exhibiting a pattern of distribution of magnetic flux densities in the gap between the stator and the rotor, which pattern represents a rectangular waveform;

Fig. 8 is a chart showing the magnetic flux density distribution pattern representing a generally trapezoidal waveform;

Fig. 9 is a chart showing the relation between the magnetic flux amount and time that is exhibited when the magnetic flux density distribution pattern represents the rectangular waveform;

Fig. 10 is a chart showing the relation between the magnetic flux amount and time that is exhibited when the magnetic flux density distribution pattern represents the trapezoidal waveform;

Fig. 11 is a chart showing the relation between the induced voltage and time that is exhibited when the magnetic flux density distribution pattern represents the rectangular waveform;

Fig. 12 is a chart showing the relation between the induced voltage and time that is exhibited when the magnetic flux density distribution pattern represents the trapezoidal waveform;

Fig. 13 is a chart showing the induced voltage versus angle α that is exhibited when the magnetic flux density distribution pattern represents the trapezoidal waveform;

Fig. 14 is a longitudinal sectional view of a self-starting synchronous motor of a type utilizing permanent magnets according to a fifth preferred embodiment of the present invention;

Fig. 15 is a transverse sectional view of the rotor used in the synchronous motor shown in Fig. 14;

Fig. 16 is a plan view of an end plate of the rotor;

Fig. 17 is an end view of the rotor;

Fig. 18 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a sixth preferred embodiment of the present invention;

Fig. 19 is an end view of the rotor used in the synchronous motor of Fig. 18;

Fig. 20 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a seventh preferred embodiment of the present invention;

Fig. 21 is an end view of an electromagnetic steel plate at one end of a rotor iron core employed in the synchronous motor of Fig. 20;

Fig. 22 is an end view of the rotor used in the synchronous motor of Fig. 20;

Fig. 23 is an end view of the rotor used in the self-starting permanent magnet synchronous motor according to an eighth preferred embodiment of the present invention;

Fig. 24 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a ninth preferred embodiment of the present invention;

Fig. 25 is a transverse sectional view of the prior art rotor;

Fig. 26 is a longitudinal sectional view of the rotor used in the synchronous motor according to a tenth preferred embodiment of the present invention;

Fig. 27 is a plan view of a rotor iron plate E;

Fig. 28 is a plan view of a rotor iron plate F;

Fig. 29 is a longitudinal sectional view of the rotor used in the synchronous motor according to an eleventh preferred embodiment of the present invention;

Fig. 30 is a plan view of the rotor iron plate G;

Fig. 31 is a longitudinal sectional view of the rotor used in the synchronous motor according to a twelfth preferred embodiment of the present invention;

Fig. 32 is a longitudinal sectional view of the rotor used in the synchronous motor according to a thirteenth preferred embodiment of the present invention;

Fig. 33 is a plan view of the rotor iron plate H;

Fig. 34 is a plan view of the rotor iron plate I;

Fig. 35 is a longitudinal sectional view of the rotor used in the self-starting permanent magnet synchronous motor according to a fourteenth preferred embodiment of the present invention;

Fig. 36 is a plan view of the electromagnetic steel plate J in the rotor iron core employed in the synchronous motor of Fig. 35;

Fig. 37 is a plan view of the electromagnetic steel plate K at opposite ends of the rotor iron core employed in the synchronous motor of Fig. 35;

Fig. 38 is a longitudinal sectional view of the rotor used in the self-starting synchronous motor of the type employing the permanent magnets

according to a fifteenth preferred embodiment of the present invention;

Fig. 39 is a plan view of the electromagnetic steel plate L at one end face of the rotor iron core used in the synchronous motor of Fig. 38;

Fig. 40 is a longitudinal sectional view of the rotor employed in the self-starting permanent magnet synchronous motor according to a sixteenth preferred embodiment of the present invention;

Fig. 41 is a longitudinal sectional view of the rotor employed in the self-starting permanent magnet synchronous motor according to a seventeenth preferred embodiment of the present invention;

Fig. 42 is an end view of the synchronous motor shown in Fig. 41;

Fig. 43 is a plan view of the electromagnetic steel plate of the rotor used in the self-starting permanent magnet synchronous motor according to an eighteenth preferred embodiment of the present invention;

Fig. 44 is a fragmentary enlarged sectional view of an entwining portion as viewed in a direction conforming to the direction of lamination in the synchronous motor of Fig. 43;

Fig. 45 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a nineteenth preferred embodiment of the present invention;

Fig. 46 is a transverse sectional view of the rotor used in the synchronous motor shown in Fig. 45;

Fig. 47 is a plan view of the end plate used in the synchronous motor shown in Fig. 45;

Fig. 48 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a twentieth preferred embodiment of the present invention;

Fig. 49 is a plan view of the end plate used in the synchronous motor shown in Fig. 48;

Fig. 50 is a cross-sectional view taken along the line C-C' in Fig. 49:

Fig. 51 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a twenty-first preferred embodiment of the present invention;

Fig. 52 is a plan view of the electromagnetic steel plate at the end of the rotor iron core employed in the synchronous motor shown in Fig. 51;

Fig. 53 is a plan view of the electromagnetic steel plate at the end of the rotor iron core employed in the self-starting synchronous motor according to a twenty-second preferred embodiment of the present invention;

Fig. 54 is a fragmentary enlarged longitudinal sectional view of the rotor employed in the synchronous motor shown in Fig. 53;

Fig. 55 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor according to a twenty-third preferred embodiment of the present invention;

Fig. 56 is a longitudinal sectional view of the synchronous motor before the end plate is fixed;

Fig. 57 is an end view of the synchronous motor of Fig. 56;

Fig. 58 is a longitudinal sectional view of the prior art rotor;

Fig. 59 is a cross-sectional view taken along the line A-A' in Fig. 58;

Fig. 60 is a longitudinal sectional view of the rotor used in the self-starting permanent magnet synchronous motor according to a twenty-fourth preferred embodiment of the present invention;

Fig. 61 is a transverse sectional view of the rotor shown in Fig. 60;

Fig. 62 is a fragmentary enlarged view showing a bridge portion; and

Fig. 63 is a plan view of the electromagnetic steel plate of the rotor

used in the self-starting permanent magnet synchronous motor according to a twenty-fifth preferred embodiment of the present invention.

Best Mode for Carrying Out the Invention

First Embodiment (Figs. 1 and 2)

Fig. 1 illustrates a transverse sectional view of a rotor used in a self-starting synchronous motor of a type utilizing permanent magnets according to a first preferred embodiment of the present invention. In this figure, reference numeral 21 represents a rotor, and reference numeral 22 represents a rotor iron core. The rotor iron core 22 has a plurality of slots 23 defined in an outer peripheral portion thereof for accommodating a corresponding number of conductor bars 24, which are integrally molded together with shortcircuit rings (not shown) at axially spaced opposite ends of the rotor iron core 22 by the use of any known aluminum die casting to thereby provide a starter squirrel cage conductor. Permanent magnets 26 are embedded in respective magnet retaining holes defined in the rotor iron core 23 at a location radially inwardly of a round row of the conductor bars 24.

So far shown in Fig. 1, two plate-like permanent magnets 26 are butted end-to-end in a generally V-shaped configuration to form a single rotor magnetic pole and, since four permanent magnets are employed in the rotor, two rotor magnetic poles are formed. Reference characters T2 and T3 represents the interval between the neighboring slots 23 positioned adjacent the rotor magnetic poles defined by the permanent magnets, and reference character T4 represents the interval between the neighboring slots 23 positioned adjacent a center point between the rotor magnetic poles. In the illustrated embodiment, the intervals T2 and T3 are chosen to be smaller than the interval T4.

Fig. 2 is a chart showing a pattern of distribution of magnetic flux densities in an air gap between the rotor and the stator, wherein the axis of

ordinates represents the magnetic flux density B and the axis of abscissas represents the angle θ of the air gap in a direction conforming to the direction of rotation of the rotor with the origin represented by the center point between the rotor magnetic pole. Since at a position adjacent the ends of the rotor magnetic poles the intervals T2 and T3 are smaller than the interval T4 at the center points of the rotor magnetic poles, magnetic fluxes emanating from the permanent magnets 26 do hardly leak to the outer peripheral surface of the rotor 21 and, instead, leak to the outer peripheral surface adjacent the center points of the rotor magnetic poles. For this reason, the pattern of distribution of the magnetic flux densities in the air gap between the stator and the rotor 21 represents a generally trapezoidal waveform or a generally sinusoidal waveform and, since as compared with a rectangular waveform the amount of change of the magnetic fluxes per unitary time increases, it is possible to increase the voltage induced across the winding of the stator.

In contrast thereto, in the prior art self-starting permanent magnet synchronous motor, the slots in the rotor iron core are circumferentially spaced at regular intervals and have the same radial lengths as measured in a direction radially of the rotor iron core and, therefore, the pattern of distribution of the magnetic flux densities tends to represents a rectangular waveform. In general, the intensity of the rotor magnetic poles brought about by the permanent magnets can be relatively grasped by measuring the magnitude of the voltage induced across the winding of the stator when the rotor is externally rotated while no voltage is applied to the motor.

The relation between the shape of the pattern of distribution of the magnetic flux densities in the air gap between the stator and the rotor and the voltage induced across the stator winding by the action of the rotor magnetic poles will now be discussed as applied to the two-pole self-starting motor of the type utilizing the permanent magnets.

The case in which the pattern $Bg(\theta)$ of distribution of the magnetic flux densities in the air gap represents a rectangular waveform $Bg1(\theta)$ is shown in Fig. 7, and the case in which the pattern of distribution of the magnetic flux densities in the air gap represents a generally trapezoidal waveform $Bg2(\theta)$ is shown in Fig. 8. The axis of abscissas represents the angle θ of the air gap in a direction conforming to the direction of rotation with the point of origin represented by the center point between the rotor magnetic poles. In Fig. 7, Bg1m represents a maximum value of $Bg1(\theta)$ that can be expressed by the following equations:

$$Bg1(\theta) = Bg1m \quad (\text{when } 0 \leq \theta \leq \pi) \cdots\cdots\cdots (1)$$

$$Bg1(\theta) = -Bg1m \quad (\text{when } \pi \leq \theta \leq 2) \cdots\cdots\cdots (2)$$

In Fig. 8, Bg2m represents a maximum value of $Bg2(\theta)$ that can be expressed by the following equations if the angle α of inclination of $Bg2(\theta)$ from $\theta = 0$.

$$Bg2(\theta) = \theta \tan \alpha \quad (\text{when } 0 \leq \theta \leq Bg2m/\tan \alpha) \cdots\cdots\cdots (3)$$

$$Bg2(\theta) = Bg2m \quad (\text{when } Bg2m/\tan \alpha \leq \theta \leq \pi - B2m/\tan \alpha) \cdots\cdots\cdots (4)$$

$$B2(\theta) = -\theta \tan \alpha + \pi \tan \alpha \quad (\text{when } \pi - Bg2m/\tan \alpha \leq \theta \leq \pi) \cdots\cdots\cdots (5)$$

It is assumed that the magnetic fluxes of the permanent magnets will nor be shortcircuited within the rotor and are all flow through the stator iron core. Accordingly, regardless of the shape of the waveform of the pattern of distribution of the magnetic flux densities in the air gap the amount of the magnetic fluxes flowing in the stator is constant and the area of surface of the waveform for each magnetic pole remains the same as can be expressed by the following equation:

$$B_{g1m}\pi = B_{g2m}[\pi - (B_{g2m}/\tan \alpha)] \cdots\cdots\cdots (6)$$

Although the stator winding is distributed over a region corresponding to one magnetic pole, the stator winding can be arranged intensively in a width of an angle π in a direction conforming to the direction of

rotation corresponding to the single magnetic pole and the number of turns thereof assumed to be n. The amount of the magnetic fluxes Φ passing through the winding during rotation of the rotor magnetic poles at an angular velocity ω(t) can be expressed by the following equation:

$$\Phi(t) = \int_{\omega t}^{\omega t+\pi} B_g(\theta)d\theta \cdots\cdots\cdots (7)$$

The amount of the magnetic fluxes Φ1(t) in the case where the pattern Bg(θ) of distribution of the magnetic flux densities in the air gap represents the rectangular waveform Bg1(θ) represents such a waveform as shown in Fig. 9 when Bg1(θ) of each of the equations (1) and (2) is substituted for Bg(θ) in the equation (7). The amount of the magnetic fluxed Φ2(t) in the case of the trapezoidal waveform Bg2(θ) represents such a waveform as shown in Fig. 10 when Bg1(θ) in each of the equations (4) and (5) is substituted for Bg(θ) in the equation (7). The axis of ordinates and the axis of abscissas in each of Figs. 9 and 10 represent the amount of the magnetic fluxes Φ and the time t, respectively.

The waveform V(t) of the voltage induced across the stator winding can be expressed by the following equation:

$$V(t) = -n\frac{d}{dt}\int_{\omega t}^{\omega t+\pi} B_g(\theta)d\theta = -\omega n[B(\theta+\pi) - B(\theta)] \cdots\cdots\cdots (8)$$

The waveform V1(t) of the induced voltage in the case where the pattern of distribution of the magnetic flux densities in the air gap represents the rectangular waveform Bg1(θ) and the waveform V2(t) of the induced voltage in the case where the pattern of distribution of the magnetic flux densities in the air gap represents the trapezoidal waveform Bg2(θ) are shown in Figs. 11 and 12, respectively, in which the axis of ordinates represents the induced voltage V(t) and the axis of abscissas represents the time t.

The induced voltage V means an effective value of the induced

voltage waveform and is expressed by the following equation:

$$V = \sqrt{\frac{1}{\pi}\int_0^{\pi} V^2(t)dt} \cdots\cdots\cdot (9)$$

Substituting the equation (8) for the equation (9) results in the induced voltage V that is expressed by the following equation (10):

$$V = \sqrt{\frac{\omega^2 n^2}{\pi}\int_0^{\pi} [B(\theta+\pi) - B(\theta)]^2 d\theta} \cdots\cdots\cdot (10)$$

The induced voltage V_1 in the case where the pattern of distribution of the magnetic flux densities in the air gap represents the rectangular waveform Bg1(θ) can be expressed by the following equation by substituting the equations (1) and (2) for the equation (10):

$$V_1 = 2\omega n B_{g2m}\sqrt{1 - \frac{4B_{g2m}}{3\pi \tan\alpha}} \cdots\cdots\cdot (11)$$

The induced voltage V_2 in the case where the pattern of distribution of the magnetic flux densities in the air gap represents the trapezoidal waveform Bg2(θ) can be expressed by the following equation by substituting the equations (3) and (4) for the equation (10):

$$V_2 = 2\omega n B_{g2m}\sqrt{1 - \frac{4B_{g2m}}{3\pi \tan\alpha}} \cdots\cdots\cdot (12)$$

V_2 is a function of the angle α shown in Fig. 8 and is shown in Fig. 13. When $\alpha = \pi/2$, V_2 takes the same value as the equation (11) and it may be said that when $\alpha = \pi/2$ in Fig. 13 the pattern of distribution of the magnetic flux densities in the air gap represents the induced voltage of the rectangular waveform. From Fig. 8, since the α is smaller than π/2 where the pattern of distribution of the magnetic flux densities in the air gap represents the trapezoidal waveform, it will readily be seen from Fig. 13 that the induced voltage where the pattern of distribution of the magnetic flux densities in the air gap represents the rectangular waveform is lower than that where the pattern of

distribution of the magnetic flux densities represents the trapezoidal waveform.

The induced voltage where the pattern of distribution of the magnetic flux densities represents the sinusoidal waveform can be similarly expressed by the equation (9), and it can be said that the induced voltage where the pattern of distribution of the magnetic flux densities in the air gap represents the rectangular waveform is lower than that where the pattern of distribution of the magnetic flux densities represents the sinusoidal waveform. Accordingly, where the pattern of distribution of the magnetic flux densities represents the rectangular waveform, the out-of-step torque is reduced due to the fact that the rotor magnetic poles are weak and the efficiency will decrease because of increase of the electric current flowing through the stator winding. Therefore, to secure the required induced voltage, it is necessary to increase the size of the permanent magnets or to employ permanent magnets having a high residual magnetic flux density and, therefore, there has been a problem in that the cost for the permanent magnets is high, accompanied by increase in cost of the motor.

According to the illustrated embodiment of the present invention, however, the voltage induced across the stator winding can be increased by rendering the pattern of distribution of the magnetic flux densities in the air gap between the stator and the rotor to represent either the approximately trapezoidal waveform or the approximately sinusoidal waveform. Therefore, it is possible to provide the high-performance, inexpensive self-starting permanent magnet synchronous motor, with no need to increase the size of the permanent magnets, nor to employ the permanent magnets having a high residual magnetic flux density.

It is to be noted that although in the foregoing embodiment reference is made to the rotor of the synchronous motor employing the two poles, the present invention may not be limited thereto and may be equally

applied to the rotor having, for example, four or more magnetic poles. Also, although the permanent magnets have been employed in the plate-like form, the present invention is not limited thereto and the present invention is equally applicable to the rotor employing permanent magnets of, for example, an arcuate shape or any other suitable shape.

Second Embodiment (Fig. 3)

Fig. 3 illustrates a transverse sectional view of the rotor used in the self-starting permanent magnet synchronous motor according to a second preferred embodiment of the present invention. In Fig. 3, the rotor 21 is shown as rotating in a direction shown by the arrow. During a loaded operation, a composite magnetic flux of the magnetic flux emanating from the stator winding and the magnetic flux emanating from the permanent magnets 26 flows in a larger quantity in a portion 29 between the neighboring slots that are located on a leading side offset θ1 angularly in a direction conforming to the direction of rotation of the rotor, than that flowing in a portion 28 between the neighboring slots that are located on a trailing side from the center of the rotor magnetic poles with respect to the direction of rotation of the rotor. The size of that portion 29, that is, the spacing T8 between the neighboring slots on respective sides of that portion 29 is chosen to be larger than the spacing T9 between the neighboring slots on respective sides of that portion 28 and, therefore, it is possible to avoid magnetic saturation of the iron core at that portion 29 between the neighboring slots to thereby secure a favorable motor characteristic.

Third Embodiment (Fig. 4)

Fig. 4 illustrates a transverse sectional view of the rotor used in the self-starting permanent magnet synchronous motor according to a third preferred embodiment of the present invention. In Fig. 4, one of the slots that is identified by 30 is the slot positioned adjacent the center of the rotor magnetic poles, and the slots 31 and 32 are positioned adjacent one of opposite ends of

the rotor magnetic poles. These slots 30, 31 and 32 have different radial lengths H30, H31 and H32, respectively, and the distances Y31 and Y32 between the slot 31 and the magnet retaining hole 25 and between the slot 32 and the magnet retaining hole 25 are chosen to be so smaller than the distance Y30 between the slot 30 and the magnet retaining hole 25 that the magnetic fluxes emanating from the permanent magnets will hardly leak to the outer peripheral surface of the rotor adjacent the ends of the rotor magnetic poles and will, instead, leak to the outer peripheral surface of the rotor adjacent the center of the rotor magnetic poles. For this reason, the pattern of distribution of the magnetic flux densities in the air gap between the stator and the rotor can represent the generally trapezoidal waveform or the generally sinusoidal waveform and, since the amount of change of the magnetic flux per unitary time is so large as compared with the rectangular waveform, the voltage induced across the stator winding can be increased. Accordingly, with no need to increase the volume of the permanent magnets or employ the permanent magnets having a high residual magnetic flux density in order to secure the required induced voltage such as implemented in the prior art, it is possible to provide the high-performance, inexpensive self-starting synchronous motor of the type employing the permanent magnets that can exhibit a required out-of-step torque and a high efficiency.

Fourth Embodiment (Fig. 5)

Fig. 5 illustrates a transverse sectional view of the rotor used in the self-starting permanent magnet synchronous motor according to a fourth preferred embodiment of the present invention. In Fig. 5, the slots 33, 34, 35, 36, 37, 38 and 39 are those positioned in a region ranging from the center to one end of the rotor magnetic poles and are spaced progressively decreasing distances Y33, Y34, Y35, Y36, Y37, Y38 and Y39, respectively, from the magnet retaining hole 35.

Arrow-headed lines shown in Fig. 5 illustrate the manner in which the magnetic fluxes of the magnetic field formed by the stator winding run across the rotor 1. For simplification purpose, the pattern of flow of the magnetic fluxed is shown only in a lower half of the rotor and not shown in an upper half of the same. As can be seen from this figure, the amount of the magnetic fluxes from the stator is small at a portion between the slot 39 adjacent the end of the rotor magnetic poles and the magnet retaining hole, but increases as the center of the magnetic poles approaches because the magnetic fluxes flowing in between the slots overlap. Thus, at a location adjacent the center of the magnetic poles, the amount of the magnetic fluxes is maximized where the magnetic fluxes of the magnetic field developed by the stator winding are intensified.

However, since the distance between each of the slots and the magnet retaining hole as well progressively increases from the end of the rotor magnetic poles towards the center of the rotor magnetic poles, any possible magnetic saturation of an iron core portion between the slots and the magnet retaining hole can be prevented, thereby ensuring a favorable motor characteristic.

Fifth Embodiment (Figs. 4 to 7)

Fig. 14 is a longitudinal sectional view of the self-starting synchronous motor of a type utilizing permanent magnets according to a fifth preferred embodiment of the present invention, and Fig. 15 is a cross-sectional view taken along the line A-A' in Fig. 14. Fig. 16 is a plan view of an end plate made of a non-magnetizable material and used for protection of the permanent magnets. Fig. 17 is an end view of the rotor after the permanent magnets have been inserted and arranged, but before the end plate is fixed to the rotor.

In these figures, reference numeral 41 represents a rotor, and reference numeral 42 represents a rotor iron core in the form of a laminated

structure of electromagnetic steel plates. Reference numeral 43 represents conductor bars molded together with shortcircuit rings 44 positioned on respective ends of the conductor bars by means of an aluminum die casting technique to provide a starter squirrel cage conductor. Reference numeral 45 represents permanent magnets each having a width Q. Reference numeral 46 represents magnet retaining holes defined in the rotor iron core 42 for accommodating therein the permanent magnets. After the aluminum die casting, two plate-like permanent magnets 45 of the same polarity are butted end-to-end in a generally V-shaped configuration to form a single rotor magnetic pole and, since four permanent magnets 45e employed in the rotor, two rotor magnetic poles are formed.

Reference numeral 47 represents a barrier for preventing a shortcircuit of the magnetic fluxes developed between the neighboring permanent magnets of different polarities, which is also filled in position by means of the aluminum die casting. Reference numeral 48 represents end plates made of a non-magnetizable material and used to protect the permanent magnets, each being formed with an engagement hole 48a. Reference numeral 49 represents axial holes defined in the rotor iron core 42 so as to extend axially thereof, which holes are filled with aluminum 50 that is used during the aluminum die casting to form the starter squirrel cage conductor. The aluminum 50 filling up the axial holes 49 protrudes axially outwardly from the opposite ends of the rotor iron core 42 to thereby define projections 50a as best shown in Fig. 14. The end plates 48 are, after the projections 50a have been passed through the associated engagement holes 48a in the end plates 48, fixed to the opposite end faces of the rotor iron core 42 by crimping or staking the projections 50a to enlarge as shown by broken lines in Fig. 14. Reference numeral 51 represents a bearing hole defined in the rotor iron core 42.

The amount of the magnetic fluxes of the permanent magnets 45

that can be obtained from the rotor is substantially proportional to the product of the width Q of the permanent magnets 45 times the length of the permanent magnets 45 as measured in the axial direction of the rotor, that is, the area of magnetic poles of the permanent magnets 45.

It is to be noted that although in the foregoing description the permanent magnets which have been magnetized are inserted and arranged, the rotor magnetic poles may be equally formed by inserting and arranging permanent magnets, which have not yet been magnetized, in the rotor iron core to complete the rotor and then polarizing the permanent magnets with the use of a magnetizing apparatus.

According to the fifth embodiment of the present invention, the angle β of end-to-end abutment of the same poles of the permanent magnets 45 is chosen to be larger than the angle α in the prior art that is 90° as shown in Fig. 25, and the width Q of each permanent magnet 45 as measured in a direction perpendicular to the longitudinal axis thereof is enlarged to a value larger than the width P in the prior art as shown in Fig. 25. Increase of the angle of end-to-end abutment of the permanent magnets and selection of the inner radial dimension c at a location adjacent the end of the rotor magnetic poles to be larger than the inner radial dimension b at a location adjacent the center of the rotor magnetic poles is effective to allow the permanent magnets of the increased width to be employed. In correspondence with the increase of the angle of end-to-end abutment of the permanent magnets 45 and increase of the width of the permanent magnets 45, each of the shortcircuit rings 44 employed in the present invention is not round in shape such as used in the prior art, but of a generally rhombic shape, as shown in Fig. 14, having its outer contour positioned outwardly of the magnet retaining holes 46 and allowing an inner diameter of the ends of the rotor magnetic poles to be greater than that of the center of the rotor magnetic poles.

The reason that the inner diameter of each of the shortcircuit rings 44a is not chosen to be round in conformity with the inner diameter at the end of the magnetic poles of the total peripheral rotor is that, if it is so chosen, the equivalent sectional surface area of each shortcircuit ring A as a whole of 44a will become so excessively small as to increase the resistance, resulting in reduction in starting capability of the motor.

As discussed above, according to the fifth embodiment of the present invention, since the permanent magnets 45 can have an increased area of surface of the magnetic poles, the amount of the magnetic fluxes of the permanent magnets required by the motor can be obtained.

Sixth Embodiment (Figs. 18 and 19)

A sixth preferred embodiment of the present invention will now be described with reference to Figs. 18 and 19, wherein Fig. 18 is a longitudinal sectional view of the self-starting synchronous motor of a type utilizing permanent magnets according to the sixth embodiment of the present invention and Fig. 19 is an end view as viewed from an S side in Fig. 18. In Fig. 19, broken lines show the position of magnet retaining holes 46 and single-dotted lines show an outer contour of the end plate 58. Although an end view of the rotor as viewed from an R side is not shown, the width and the angle of end-to-end abutments of the permanent magnets 45 and the inner diametric shape of the shortcircuit ring A of 44a are all similar to those in the previously described first embodiment of the present invention, and the shortcircuit ring B of 44b on the opposite S side has an inner diameter that is round and is so chosen to be small as to allow it to be positioned inwardly of the magnet retaining holes 46.

Referring to Figs. 18 and 19, the end plate 58 is similarly arranged in abutment with an end face of the rotor iron core 42 on the S side and is of a shape sufficient to encompass the magnet retaining holes 46 and, accordingly, there is no possibility that the die cast aluminum may leak into the magnet

retaining holes 46 which would otherwise render it difficult to insert the permanent magnets 45.

Seventh Embodiment (Figs. 20 to 22)

A seventh preferred embodiment of the present invention will now be described with reference to Figs. 20 to 22. Fig. 20 is a longitudinal sectional view of the self-starting synchronous motor of a type utilizing permanent magnets according to the seventh embodiment of the present invention, Fig. 21 is a plan view of one or a plurality of electromagnetic steel plates 59 at one end on the S side of the rotor iron core 2, and Fig. 22 is an end view as viewed from the S side. Although an end view of the rotor as viewed from the R side is not shown, the width and the angle of end-to-end abutments of the permanent magnets 45 and the inner diametric shape of the shortcircuit ring A of 44a are all similar to those in the previously described fifth embodiment of the present invention.

Referring to Figs. 20 to 22, the shortcircuit ring C of 44c on the S side has its inner diameter or bore which is round and is so chosen as to be positioned inwardly of the magnet retaining holes 46. One or a plurality of electromagnetic steel plates 59 at the end on the S side of the rotor iron core 42 is provided with slots of the same shape and size defined at the same position as the electromagnetic steel plates other than those at the end, but no magnetic retaining hole 46 is provided. Accordingly, even though the inner diameter of the shortcircuit ring C of 44c is small, there is no possibility that the die cast aluminum will leak into the magnet retaining holes 46 to render it to be difficult to insert the permanent magnets.

Eighth Embodiment (Fig. 23)

An eighth embodiment of the present invention will be described with reference to Fig. 23 which is an end view of the rotor as viewed in a direction conforming to the direction of insertion of permanent magnets 45,

showing the rotor after the permanent magnets 45 have been inserted and arranged, but before the end plate is mounted.

Referring to Fig. 23, the inner diameter or bore of the shortcircuit ring D of 44d is of a shape conforming to and extending along the magnet retaining holes 46. This design permits the permanent magnets 45 to be inserted along a wall surface inside the inner diameter or bore of the shortcircuit ring D of 44d, thereby facilitating a job of insertion of the permanent magnets to thereby increase the ease to assembly.

Ninth Embodiment (Fig. 24)

A ninth preferred embodiment of the present invention will be described with reference to Fig. 24 and also to Fig. 17 used in connection with the fifth embodiment of the present invention. Fig. 24 illustrates a transverse sectional view of the self-starting synchronous motor of the type employing the permanent magnets according to the ninth embodiment of the present invention. In this figure, reference numeral 61 represents a stator, and reference numeral 62 represents a stator iron core in the form of a laminate structure of electromagnetic steel plates, which laminate structure has a laminate thickness indicated by Ls. Reference numeral 63 represents a stator winding wound around the stator iron core 62. The rotor 41 employed therein is substantially identical with that described in connection with the fifth embodiment with reference to Fig. 17 and are not therefore described for the sake of brevity. however, as is the case with the rotor shown in Fig. 17, by increasing the width of the permanent magnets 45 as measured in a direction perpendicular to the longitudinal axis thereof to thereby increase the area of surface of the magnetic poles of the permanent magnets 45 to increase the amount of the magnetic fluxes emanating from the permanent magnets 45, and also by designing the inner diameter or bore of the shortcircuit ring A of 44a to be positioned outwardly of the magnet retaining holes 46 and, again by selecting the inner

radial dimension adjacent the end of the rotor magnetic poles of the shortcircuit ring A of 44a to be larger than that adjacent the center of the rotor magnetic poles, the laminate thickness of the electromagnetic steel plates forming the rotor iron core 42 can advantageously reduced to a value substantially equal to the laminate thickness Ls of the stator iron core.

The motor of the type utilizing the permanent magnets is generally designed by selecting the axial length of the permanent magnets to be greater than the laminate thickness of the stator iron core so that portions of the magnetic fluxes of the permanent magnets, which emerge outwardly from the opposite ends of the stator iron core, can flow inwardly of the stator iron core from the opposite ends thereof to thereby increase the amount of the magnetic fluxes that runs through the whole of the stator iron core and, for that purpose, the laminate thickness of the rotor iron core is chosen to be greater than the laminate thickness of the stator iron core. In contrast thereto, according to the ninth embodiment of the present invention, the design has been employed as hereinabove described to render the laminate thickness Ls of the stator iron core and the laminate thickness L_R of the rotor iron core to be substantially equal to each other.

In view of the foregoing, the number of the electromagnetic steel plates for each of the stator and rotor iron cores that are simultaneously blanked within the same dies is substantially equal for the both and, therefore, production of surplus electromagnetic steel plates can be suppressed to thereby reduce the cost.

Tenth Embodiment (Figs. 26 to 28)

A tenth preferred embodiment of the present invention will now be described with reference to Figs. 26 to 28. Fig. 26 is a longitudinal sectional view of the rotor used in the synchronous motor according to the tenth embodiment of the present invention. In Fig. 26, reference numeral 71

represents a rotor, and reference numeral 72 represents a rotor iron core. Reference numeral 72a represents a rotor iron core formed by laminating rotor iron plates E, and one of the rotor iron plates E is shown in Fig. 27. In Fig. 27, reference numeral 73 represents magnet retaining holes, and when the rotor iron plates E are laminated, the magnet retaining holes 73 are axially aligned with each other as shown in Fig. 26 with the respective permanent magnets 74 subsequently embedded therein.

Reference numeral 72b1 shown in Fig. 26 represents a rotor iron core formed by laminating rotor iron plates F to an axial end face of the rotor iron core 72a, one of the rotor iron plates F being shown in Fig. 28 in a plan view. In Fig. 28, reference numeral 77 represents magnetic flux shortcircuit preventive holes that are arranged at the same position as the magnet retaining holes 73 in the rotor iron plates E, but have a width U smaller than the width T of the magnet retaining holes 73. When the rotor iron plates F are laminated to the axial end face of the rotor iron core 72a, the magnetic flux shortcircuit preventive holes 77 are axially communicated with the magnet retaining holes 73 as shown in Fig. 26. In Fig. 26, reference numeral 72c1 represents a rotor iron core made of one or more rotor iron plates E laminated to the axial end face of the rotor iron core 72b1. Also, in Fig. 26, reference numeral 76 represents an end plate made of a non-magnetizable material and having a shape sufficient to overlay the magnet retaining holes 73 and the magnetic flux shortcircuit preventive holes 77 so as to prevent debris of the permanent magnets 74, which would be generated at the time the permanent magnets 74 are inserted in and embedded in the magnet retaining holes 73, from flowing outwardly and also to prevent external foreign matter from being trapped into the magnet retaining holes 73.

As shown in Fig. 26, an axial end face 79 of each of the permanent magnets 79 is held in engagement with an outer peripheral edge 78

of the respective magnetic flux shortcircuit preventive hole 77 on an abutment face of the rotor iron core 72b1 that is in engagement with the rotor iron cores 72a and, accordingly, magnetic fluxes 80 leaking between N and S poles at the respective opposite ends of the permanent magnets 74 run from the rotor iron cores 72a back to the permanent magnets 74 through the rotor iron core 72b1, then across the magnetic flux shortcircuit preventive holes 77 and finally through the rotor iron cores 72b1 and 72a. The leaking magnetic fluxes 80b1 runs from the rotor iron cores 72a back to the permanent magnets 74 through the rotor iron core 72b1, then through the rotor iron core 72c1, across the magnet retaining holes 73, again through the rotor iron core 72c1, the rotor iron core 72b1 and finally through the rotor iron core 72a. Where the rotor iron core 72b1 is made up of a single rotor iron plate or a plurality of rotor iron plates F in a number as small as possible so long as the permanent magnets can be positioned, a magnetic circuit through which the leaking magnetic fluxes 80a1 run can have a magnetic resistance of a magnitude sufficient to minimize the leaking magnetic fluxes 80a1. Also, since the width T of the magnet retaining holes 73 in the rotor iron plate E forming the rotor iron core 72c1 is so larger than the width U of the magnetic flux shortcircuit preventive hole 77 in the rotor iron plate F that, as compared with the case in which the rotor iron core 72c1 is prepared from the rotor iron plate F, the magnetic circuit through which the leaking magnetic fluxes 80b1 run can have a magnetic resistance of a magnitude sufficient to minimize the leaking magnetic fluxes 80b1. Therefore, the motor characteristic can be increased.

Also, since the permanent magnets 74 attracts and is therefore held in engagement with the outer peripheral edge 78 of the magnetic flux shortcircuit preventive hole 77 in the rotor iron core 72b1, the permanent magnets 74 can be accurately positioned with respect to the axial direction thereof only by means of the rotor iron cores 72 with no holder employed,

thereby reducing the cost for assembly and component parts.

It is to be noted that the number of the rotor iron plates F laminated is so chosen that a point intermediate of the axial length of the rotor iron cores 72 can match with a point intermediate of the axial length of the permanent magnets 74, and this equally applies to any one of the embodiments of the present invention that follow.

It is also to be noted that where the permanent magnets are made of a rare earth metal of, for example, Nd-Fe-B system, since the magnet made of the rare earth metal of the Nd-Fe-B system is known to exhibit a high residual magnetic flux density, the volume of the rotor and the motor as a whole can advantageously be reduced.

In describing the tenth embodiment of the present invention, the permanent magnets has been employed in the form of a generally plate-like configuration, but the present invention may not be limited thereto and can be equally applied to the rotor employing the permanent magnets of any suitable shape such as, for example, an arcuate shape.

Eleventh Embodiment (Figs. 29 and 30)

An eleventh preferred embodiment of the present invention will be described with reference to Figs. 29 and 30, wherein Fig. 29 is a longitudinal sectional view of the rotor used in the synchronous motor and Fig. 30 is a plan view of the rotor iron plate G. As shown in Fig. 29, reference numeral 72d1 represents a rotor iron core comprising a rotor iron core 72a having its axial end face to which rotor iron plates G are laminated. Since the rotor iron plates G have no magnet retaining hole defined therein, lamination of the rotor iron plates G to the axial end face of the rotor iron core 72a results closure of the magnet retaining holes 73.

Since the axial end face 81 of the permanent magnets 74 is held in engagement with an abutment face of the rotor iron core 72d1 that is held in

engagement with the rotor iron core 72a, magnetic fluxes 80c1 leaking from the axial end of the permanent magnets 74 runs from the rotor iron core 72a back to the permanent magnets 74 through the rotor iron core 72d1 and then through the rotor iron core 72a. Also, since the permanent magnets 74 attract and are therefore held in engagement with the axial end face 82 of the rotor iron core 72d1, the permanent magnets 74 can be accurately positioned with respect to the axial direction thereof with no need to use any holder, thereby reducing the cost for assembly and component parts.

Also, since the magnet retaining holes 73 in the rotor iron core 72a are closed at one end by the rotor iron core 72d1, positioning of a single end plate 76 at the opposite end is sufficient to close the opposite ends of the magnet retaining holes 73. While in the previously described tenth embodiment of the present invention, two end plates 76 are required, the eleventh embodiment requires the only end plate 6 and, therefore, the cost for assembly and component parts can further be reduced.

The rotor iron plate E and the rotor iron plate G can easily manufactured by controlling loading and unloading of blanking dies, that are used to form the magnet retaining hole 73, during a blanking process. Therefore, no blanking dies that are required in the previously described tenth embodiment of the present invention to form the magnetic flux shortcircuit preventive hole 77 in the rotor iron plate F is needed, making it possible to simplify the structure of the dies themselves.

Twelfth Embodiment (Fig. 31)

Fig. 31 illustrates a longitudinal sectional view of the rotor used in the synchronous motor according to a twelfth embodiment of the present invention. An axial end face of the rotor iron core 72d2 opposite to that with which the axial end face 81 of the permanent magnets 74 are held in engagement is provided with a rotor iron core 72c2 of a laminated structure

including rotor iron plates E.

Since the axial end face 81 of the permanent magnet 74 is held in engagement with the axial end face 82 of the rotor iron core 72d2, magnetic fluxes 80c2 leaking at the axial end of the permanent magnet 74 run from the rotor iron core 72a back to the permanent magnet 74 through the rotor iron core 72d2 and then through the rotor iron core 72a. The leaking magnetic fluxes 80b2 runs from the rotor iron cores 72a back to the permanent magnet 74 through the rotor iron core 72d2, then through the rotor iron core 72c2, across the magnet retaining holes 73, again through the rotor iron core 72c2, the rotor iron core 72d2 and finally through the rotor iron core 72a.

Since the leaking magnetic fluxes 80c1 traverse the magnet retaining holes 73, as compared with the magnetic resistance of the magnetic circuit through which the leaking magnetic fluxes 80c1 run in the previously described eleventh embodiment of the present invention, the magnetic circuit through which the leaking magnetic fluxes 80b2 run in this twelfth embodiment has a relatively high magnetic resistance and, therefore, the sum of the leaking magnetic fluxes 80c2 and 80b2 in this twelfth embodiment is smaller relative to the leaking magnetic fluxes 80c1 in the previously described eleventh embodiment. Accordingly, since the leaking magnetic fluxes can be reduced as compared with that in the previously described embodiment, the motor characteristic can be increased.

Thirteenth Embodiment (Figs. 32 to 34)

A thirteenth preferred embodiment of the present invention will be described with reference to Figs. 32 to 34. Fig. 32 illustrates a longitudinal sectional view of the rotor used in the synchronous motor according to the thirteenth embodiment of the present invention. In this figure, reference numeral 83 represents a rotor and reference numeral 84 represents a rotor iron core. Reference numeral 84a represents a rotor iron core made up of a

laminate of rotor iron plates H. Reference numeral 84b represents a rotor iron core made up of a laminate of rotor iron plates I, one of which is shown in Fig. 34 in a plan view.

Fig. 33 illustrates a plan view of the rotor iron plate H. In this figure, reference numeral 85 represents a plurality of slots for accommodating conductor bars 86a of the starter squirrel cage conductor, and reference numeral 73 represents magnet retaining holes.

Referring to Fig. 34, reference numeral 87 represents a plurality of slots for accommodating the conductor bars 86a of the starter squirrel cage conductor shown in Fig. 32, which slots 86a are of the same shape as the slots 85 in the rotor iron plate H and are positioned at the same position as the slots 85 in the rotor iron plate H. Reference numeral 77 represents magnetic flux shortcircuit preventive holes that are positioned at the same position as the magnet retaining holes 73 in the rotor iron plate H of Fig. 33, but have a width U smaller than the width T of the magnet retaining holes 73.

Referring back to Fig. 32, reference numeral 84c represents a rotor iron core made up of one rotor iron plate E or a laminate of rotor iron plates E. By the use of any known aluminum die casting technique, the conductor bars 86a and shortcircuit rings 86b are formed integrally together to define the starter squirrel cage conductor. By arranging the starter squirrel cage conductor in the rotor 83, the self-starting synchronous motor of the type employing the permanent magnets can be obtained which operates as an inductor motor at the time of starting thereof and as a synchronous motor entrained by a synchronous speed upon arrival at the synchronous speed. Even in this case, since as is the case with the previously described tenth embodiment of the present invention, the rotor iron core 84b having the magnetic flux shortcircuit preventive holes 77 defined therein are employed and the rotor iron plates E are laminated, the leaking magnetic fluxes between the N

and S poles at the axially opposite ends of the permanent magnets 74 can be reduced, thereby increasing the motor characteristic.

Even in the self-starting synchronous motor of the type employing the permanent magnets in which the starter squirrel cage conductor is arranged such as in this thirteenth embodiment, the permanent magnets 74 can be accurately positioned only by the rotor iron core 84 with no need to employ any holder and, therefore, the cost for assembly and component parts can be reduced advantageously.

Fourteenth Embodiment (Figs. 35 to 37)

A fourteenth preferred embodiment of the present invention will be described with reference to Figs. 35 to 37, wherein Fig. 35 illustrates a longitudinal sectional view of the rotor used in the synchronous motor according to the fourteenth embodiment of the present invention, Fig. 36 illustrates a plan view of an electromagnetic steel plate J positioned inwardly of opposite axial ends of the rotor, iron core and Fig. 37 illustrates a plan view of an electromagnetic steel plate K positioned at the opposite axial ends of the rotor iron core.

Referring now to Figs. 35 to 37, reference numeral 91 represents a rotor, and reference numeral 92 represents a rotor iron core of a laminated structure including the electromagnetic steel plates J 110 and the electromagnetic steel plates K 111. The electromagnetic steel plates J 110 and K 111 are formed with respective conductor bar slots 112 of the same size, respective barrier slots 113 of the same size for preventing the magnetic flux shortcircuit, respective holes 99 of the same size and respective bearing holes 114 of the same size, which are aligned with each other. Reference numerals 96b and 96a represent magnet retaining holes defined at the same position, wherein respective hole widths R and S as measured in a direction radially thereof are so chosen as to satisfy the relationship $R < S$.

Reference numeral 93 represents conductor bars made of aluminum and filled in the respective slots 112. The conductor bars 93 are integrally molded together with the shortcircuit rings 94 at the axially opposite ends of the rotor iron core 92 by means of any known aluminum die casting technique to thereby form the starter squirrel cage conductor. Reference numeral 95 represents permanent magnets, every two of which are, after the aluminum die casting, held in end-to-end abutment to represent a generally V-shaped configuration and are then inserted and arranged in the magnet retaining holes 96 and 96a so that the two pairs of the permanent magnets 95 can define two magnetic poles. The barrier slots 113 are filled ;up with aluminum injected during the aluminum die casting to avoid any possible shortcircuit between the neighboring permanent magnets of the different polarities. Reference numeral 98 represents a non-magnetizable end plate for protection of the permanent magnets 95, which end plate has an engagement hole 98a defined therein. Reference numeral 99 represents an axial hole defined in the rotor iron core 92 so as to extend axially thereof, in which hole is filled aluminum 100 that is injected during the aluminum die casting to form the starter squirrel cage conductor. The aluminum 100 filled in the axial hole 99 has projections 100a protruding outwardly from the axially opposite ends of the rotor iron core 92. The end plates 98 are, after the engagement holes 98a have received therein the projections 100a, fixed to the respective axial end faces of the rotor iron core 92 by staking or crimping the projections 100a to enlarge as shown by broken lines. Reference numerals 101 and 114 represents respective bearing holes.

It is to be noted that although in the foregoing description the permanent magnets which have been magnetized are inserted and arranged, the rotor magnetic poles may be equally formed by inserting and arranging permanent magnets, which have not yet been magnetized, in the rotor iron core

to complete the rotor and then polarizing the permanent magnets with the use of a magnetizing apparatus.

During the manufacture of the self-starting synchronous motor of the structure described above, and at the time the shortcircuit rings 94 formed by the aluminum die casting cool, the outer diameter of the magnet retaining holes 96a in the electromagnetic steel plates K 111 at each axial end of the rotor iron core 92 deforms and contracts under the influence of a force of shrinkage acting in an inner radial direction. However, since the hole width S of the magnet retaining holes 96a is sufficiently larger than the hole width R of the magnet retaining hole 96 in the electromagnetic steel plates J that are small of the shrinkage force of the shortcircuit rings 94, there is no possibility that as a result of reduction in gap between the permanent magnets 95b and the magnet retaining holes 96a that is brought about by deformation and shrinkage insertion of the permanent magnets 95 into the respective magnet retaining holes 96a is difficult to achieve.

The hole width S of the magnet retaining holes 98a is so chosen as to be slightly greater than R by a quantity that a side adjacent an outer diameter of the hole width S when receiving the shrinkage force of the shortcircuit ring 94 can line up with a side adjacent an outer diameter of the hole width R of the magnet retaining hole 96, and accordingly, a possibility can be avoided which would, as a result of reduction of the coefficient of permeance of the magnetic circuit can be lowered, the motor characteristic may correspondingly decrease.

As hereinabove described, the self-starting synchronous motor of the type employing the permanent magnets according to the fourteenth embodiment is advantageous in that the permanent magnets 5 can be easily inserted subsequent to the aluminum die casting and that a high-performance motor characteristic can be maintained.

Fifteenth Embodiment (Figs. 38 and 39)

A fifteenth preferred embodiment of the present invention will be described with reference to Figs. 38 and 39 in combination with Figs. 36 and 37. Fig. 38 is a longitudinal sectional view of the rotor used in the self-starting synchronous motor of the type employing the permanent magnets according to the fifteenth preferred embodiment of the present invention, and Fig. 39 is a plan view of the electromagnetic steel plate L at one end face of the rotor iron core 92 of Fig. 38.

Referring now to Figs. 38 and 39, one or a plurality of electromagnetic steel plates L 120 at one end of the rotor iron core on the P side have no magnet retaining hole defined therein. The electromagnetic steel plates on the axially opposite ends of the rotor iron core 92 are laminated with the same electromagnetic steel plates K 111 as those shown in Fig. 37 in connection with the fourteenth embodiment and the electromagnetic steel plates J 110 are laminated inwardly of the opposite ends. Since the axial end face of the permanent magnets abuts against the electromagnetic steel plate L, the number of the electromagnetic steel plates L laminated is so chosen that respective axial centers of the rotor iron core and the permanent magnets can match with each other.

In the fifteenth embodiment of the present invention which is so constructed as hereinabove described, since the rotor 91 is such that one or a plurality of the electromagnetic steel plates L 120 at the end of the rotor iron core 92 on the P side has no magnet retaining hole defined therein, the only end plate 98 is sufficient on the opposite Q side and, therefore, the cost for material and the number of fitting steps can be reduced advantageously. Also, since the hole width S of the magnet retaining holes 96a in the electromagnetic steel plates K 111 on the axially opposite ends of the rotor iron core 2 is sufficiently greater than the hole width R of the magnet retaining holes 96 in the

inside electromagnetic steel plates J 110, even though a radially inwardly shrinking deformation occurs under the influence of the radially inwardly acting shrinkage force from the shortcircuit rings 94 subsequent to the aluminum die casting, the permanent magnets 95 can be carried out without being disturbed and, since as is the case with the first embodiment of the present invention, the gaps between the permanent magnets 95b and the magnet retaining holes in the rotor iron core 92 are properly maintained, a high-performance motor characteristic can be maintained.

Sixteenth Embodiment (Fig. 40)

A sixteenth preferred embodiment of the present invention will be described with reference to Fig. 40 in combination with Figs. 36 to 38. Fig. 40 is a longitudinal sectional view of the rotor employed in the self-starting permanent magnet synchronous motor according to the sixteenth embodiment. As shown in Fig. 40, one or a plurality of electromagnetic steel plates L 120 shown in Fig. 40 and having no magnet retaining holes defined therein are laminated to one end of the rotor iron core 92 on the P side, and one or a plurality of electromagnetic steel plates K 111 having the magnet retaining holes of a relatively great hole width are laminated to the opposite end of the rotor iron core 92 on the Q side. Since no magnet retaining hole is defined in the electromagnetic steel plates L 120 on the P side end, the shrinkage stress of the shortcircuit ring 94 has no concern therewith and, therefore, the permanent magnets 95 can easily be inserted in the rotor iron core 92 if the electromagnetic steel plates K 111 having the magnet retaining holes 96 of a relatively great hole width are arranged only on the Q side. Accordingly, the rotor iron core 92 can be assembled with a minimized combination of the electromagnetic steel plates J 110, K 111 and L 120, thereby facilitating the manufacture thereof and also maintaining a high-performance motor characteristic.

Seventeenth Embodiment (Figs. 41 and 42)

A seventeenth preferred embodiment of the present invention will be described with reference to Figs. 41 and 42 in combination with Fig. 39. Fig. 41 is a longitudinal sectional view of the rotor employed in the self-starting permanent magnet synchronous motor according to the seventeenth embodiment and Fig. 42 is an end view of the synchronous motor viewed from the P side in Fig. 41.

The basic structure of the rotor in the seventeenth embodiment is substantially similar to that described in connection with any of the fifteenth and sixteenth embodiments.

Referring to Figs. 41 and 42, the shortcircuit ring 94a having a reduced inner diameter is formed on an outer end face of the electromagnetic steel plates L 120 shown in Fig. 39 and having no magnet retaining hole defined therein on the P side, by means of the aluminum die casting. The inner diameter of the shortcircuit ring 94a is such that it can be enclosed inwardly of the whole of the magnet retaining holes 96 and 96a defined respectively in the electromagnetic steel plates j and K as shown by the broken lines, or partly inwardly thereof although not shown. Since the electromagnetic steel plates L 120 have no magnet retaining hole such as identified by 96, there is no possibility that during the aluminum die casting aluminum may penetrate into the magnet retaining holes 96. In view of the foregoing, the shortcircuit ring 94a can have an increased cross-sectional surface area to thereby reduce a secondary resistance of the rotor, the rotational speed of the motor at the time of a maximum torque en route the synchronous speed and the at the time of the maximum torque can increase to facilitate a synchronous entanglement, thereby increasing the starting performance of the motor.

Eighteenth Embodiment (Fig. 43)

An eighteenth preferred embodiment of the present invention will

be described with reference to Fig. 43 which shows a plan view of an electromagnetic steel plate M for the rotor of the self-starting permanent magnet synchronous motor according to the eighteenth embodiment.

The basic structure of the rotor in the eighteenth embodiment is substantially similar to that described in connection with any of the eighteenth and seventeenth embodiments. Referring now to Fig. 43, reference numeral 131 represents entwining portions for lamination of the electromagnetic steel plates. As shown in Fig. 43, when the electromagnetic steel plates are blanked one by one, press projections are formed and are laminated together while sequentially entwined therewith to thereby form the rotor iron core. In such case, the entwining portions 131 are defined at respective locations outwardly of the magnet retaining holes 132. Reference numeral 132a represents an enlarged portion in which the hole width of a portion of each magnet retaining hole 132 adjacent the corresponding entwining portion 131 is enlarged radially outwardly by a required quantity V towards such corresponding entwining portion 131. Reference numeral 133 represents a pincer portion of the electromagnetic steel plate M 130 bound between the corresponding entwining portion 131 and the enlarged portion 132a of each magnet retaining hole.

According to the eighteenth embodiment, since the provision has been made of the enlarged portion 132a in which the hole width of each magnet retaining hole adjacent the corresponding entwining portion 131 is increased by the quantity V towards the entwining portion 131, even though the corresponding pincer portion 133 is deformed to protrude inwardly of the associated magnet retaining hole 132 under the influence of press stresses during formation of the corresponding entwining portion by the use of a press work, the deformation can be accommodated within the enlarged quantity V and, therefore, the permanent magnet can easily be inserted without being disturbed. Also, since the enlarged portion 132a has a length W that is small in

correspondence with the length of the adjacent entwining portion 131 and, also, the specific value of the quantity V is small and will decrease in response to inward deformation of the pincer portion 133, the gap with the permanent magnet is very minute and the coefficient of permeance of the magnetic circuit will not decrease substantially, thereby securing a high-performance motor characteristic.

It is to be noted that in the foregoing description the entwining portion 131 has been described as positioned outside the associated magnet retaining hole 132, but it may be positioned inside the associated magnet retaining hole and even in this case similar effects can be obtained.

It is also to be noted that since if each of the permanent magnets is made of a rare earth metal of, for example, Nd-Fe-B system, a high magnetic force can be obtained and, therefore, the rotor and the motor as a whole can advantageously be manufactured in a compact size and lightweight.

It is further to be noted that although in the foregoing embodiment reference is made to the rotor of the synchronous motor employing the two poles, the present invention may not be limited thereto and may be equally applied to the rotor having, for example, four or more magnetic poles.

Again, although in any one of the foregoing embodiments the single pole has been formed by abutting two plate-like permanent magnets of the same polarity in end-to-end fashion, the present invention may not be limited thereto and the single pole may be formed by the use of a single permanent magnet or three or more plate-like permanent magnets of the same polarity. Similarly, although the permanent magnets have been employed in the plate-like form, the present invention is not limited thereto and the present invention is equally applicable to the rotor employing permanent magnets of, for example, an arcuate shape or any other suitable shape.

Nineteenth Embodiment (Figs. 45 to 47)

A nineteenth preferred embodiment of the present invention will now be described with reference to Figs. 45 to 47, wherein Fig. 45 illustrates a longitudinal sectional view of the rotor used in the self-starting synchronous motor of the type employing the permanent magnets according to the nineteenth embodiment, Fig. 46 is a transverse sectional view of the rotor and Fig. 47 is a plan view of an end plate. In these figures, reference numeral 141 represents a rotor, and reference numeral 142 represents a rotor iron core made of a laminate of electromagnetic steel plates. Reference numeral 143 represents conductor bars which are molded integrally together with shortcircuit rings 144, positioned at axially opposite ends of the rotor iron core 142, by the use of the aluminum die casting technique to form a starter squirrel cage conductor. Reference numeral 145 represents permanent magnets, every two of which are held in end-to-end abutment to represent a generally V-shaped configuration and are so arranged that the two pairs of the permanent magnets 145 can define two magnetic poles. Reference numeral 147 represents shortcircuit preventive barriers for preventing shortcircuit of the magnetic fluxes between the permanent magnets of the different polarities and filled up with aluminum die cast. Reference numeral 148 represents an end plate made of a non-magnetizable material and used of protection of the permanent magnets 145, in which engagement holes 148a are defined. Reference numeral 149 represents an axial hole defined in the rotor iron core 142 so as to extend axially thereof, in which hole is filled aluminum 150 that is injected during the aluminum die casting to form the starter squirrel cage conductor. The aluminum 150 filled in the axial hole 149 has projections 150a protruding outwardly from the axially opposite ends of the rotor iron core 142. The end plates 148 are, after the engagement holes 148a have received therein the projections 150a, fixed to the respective axial end faces of the rotor iron core 142 by staking or crimping the projections 150a to enlarge as shown by broken lines.

As hereinabove described, in the self-starting synchronous motor according to the nineteenth embodiment, since the projections 150a used to secure the end plates 148 to the axially opposite ends of the rotor 141 are formed simultaneously with formation of the starter squirrel cage conductor by the use of the aluminum die casting technique and since the end plates 148 can be firmly secured to the axially opposite end faces of the rotor iron core 142 merely by staking or crimping the projections 150a, the cost for the material and the number of assembling steps can be considerably reduced as compared with the prior art in which bolts are employed, thereby making it possible to provide an inexpensive self-stating synchronous motor of the kind employing the permanent magnets.

Twentieth Embodiment (Fig. 48 to 50)

A twentieth preferred embodiment of the present invention will now be described with reference to Figs. 48 to 50, wherein Fig. 48 is a longitudinal sectional view of the self-starting permanent magnet synchronous motor, Fig. 49 is a plan view of the end plate used in the synchronous motor shown in Fig. 48, and Fig. 50 is a cross-sectional view taken along the line C-C' in Fig. 49. As shown in Fig. 48, the shortcircuit rings 144a are formed so as to cover the end plates 152. Accordingly, the end plate 152 is integrated with the axially end face of the rotor iron core 152 by means of the aluminum die casting used to form the starter squirrel cage conductor.

Referring to Figs. 49 and 50, the end plate 152 is formed with two projections 152a each having a respective hole 152 defined therein so as to extend completely across the thickness thereof. Prior to the aluminum die casting, the end plate 152 is secured to the corresponding end face of the rotor iron core 142 with the projections 152a protruding through the holes 149 to thereby position the respective end plate 152 so that the end plate 152 will not displace during the aluminum die casting in which a high pressure may act on

the end plate 152 to allow the end plate 152 to be firmly connected to the associated end face of the rotor iron core 142 without being displaced in position. On the other hand, the end plate 148, the end plate 148 is, as is the case with that in the previously described nineteenth embodiment, fixed to the end face of the rotor iron core 142 by staking or crimping the projections 150a after the end plate 148 has been engaged with the projections 150a for fixing the end plate.

As hereinabove described, since the end plate 152 is integrally connected with the rotor iron core 142 by means of the aluminum die casting, a job of securing the end plate by staking or crimping the projections 150a has to be performed only in association with the end plate 148 and, therefore, as compared with the previously described nineteenth embodiment, the number of assembling steps can further be reduced.

Twenty-first Embodiment (Figs. 51 and 52)

A twenty-first preferred embodiment of the present invention will be described with reference to Figs. 51 and 52, wherein Fig. 51 illustrates a longitudinal sectional view of the rotor used in the self-starting synchronous motor and Fig. 52 is a plan view of an electromagnetic steel plate positioned at an axial end of the rotor iron core used in the rotor of Fig. 51. Referring to Figs. 51 and 52, the electromagnetic steel plate 160 positioned at the axial end of the rotor iron core 142 having conductor bar slots 161, barrier holes 162 for preventing the magnetic flux shortcircuit, holes 149 and a bearing hole 150 all defined therein is of the same shape as that used at a different position, but no magnet retaining hole 146 defined therein. Although this electromagnetic steel plate 160 is manufactured by blanking with the use of the same core dies as used for the other electromagnetic steel plates, since mold pieces used to form the magnet retaining holes 146 in the electromagnetic steel plate 160 by the use of a blanking technique are of a type that can be removably mounted on a

die assembly, it is easy to avoid formation of the magnet retaining holes 146 in the electromagnetic steel plate 160 at the time the latter is blanked off from a metal sheet. Accordingly, the rotor iron core 142 can be integrally formed together with the electromagnetic steel plate 160 and, if this is aluminum die cast, the starter squirrel cage conductor can be formed.

Because of the structure described above, the end plate on the other end is needed and, as is the case with the previously described twentieth embodiment, a job of securing the end plate by staking or crimping the projections 150a has to be performed only in association with the end plate 148 and, therefore, as compared with the previously described nineteenth embodiment, the number of assembling steps can further be reduced.

Twenty-second Embodiment (Figs. 53 and 54)

A twenty-second preferred embodiment of the present invention will now be described with reference to Figs. 53 and 54, wherein Fig. 53 is a plan view of the electromagnetic steel plate at the axial end of the rotor iron core and Fig. 54 is a fragmentary enlarged view showing a portion of the rotor 141.

Referring to Figs. 153 and 154, reference numeral 162 represents an electromagnetic steel plate disposed at an axial end of the rotor iron core 141, and reference numeral 164 represents a projection protruding inwardly of the permanent magnets 154 at a location where the electromagnetic steel plate 163 engages the permanent magnets 145. Accordingly, the permanent magnets 145 are axially positioned with the projection 164 in the electromagnetic steel plate 163 brought into engagement therewith.

According to the embodiment shown in Figs. 53 and 54, shortcircuit of the magnetic fluxes between the front and rear, different poles of the permanent magnets 145 through the electromagnetic steel plate 163 can be reduced considerably, thereby to increase the performance of the motor. It is to

be noted that although this electromagnetic steel plate 163 is manufactured by blanking with the use of the same core dies as used for the other electromagnetic steel plates, since mold pieces used to form the projection 163 are of a type that can be removably mounted on a die assembly, the rotor iron core 142 can easily be formed integrally together with the electromagnetic steel plate 163.

Twenty-third Embodiment (Figs. 55 to 57)

A twenty-third embodiment of the present invention will be described with reference to Figs. 55 to 57, wherein Fig. 55 is a longitudinal sectional view of the complete rotor used in the self-starting synchronous motor according to this embodiment, Fig. 56 is a longitudinal sectional view of the rotor before the end plates are fixed, and Fig. 57 is an end view of the rotor shown in Fig. 56. Referring to Figs. 56 and 57, the end plate 171 has its outer periphery formed with radial projections 171a and, on the other hand, the shortcircuit ring 170 formed by the aluminum die casting has an inner periphery formed with a radial recesses 170a complemental in shape to the radial projections 171a in the end plate 171. After the radial projections 171a in the end plate 171 have been engaged in the corresponding radial recesses 170a in the shortcircuit ring 170, peripheral portions of the radial recesses 170a in the shortcircuit ring 170 are axially pressed to deform as shown by 170b in Fig. 55 to thereby fix the end plate 171 to the rotor iron core 2.

According to the twenty-third embodiment, fixing of the end plate 171 can easily be accomplished merely by pressing the radial recesses 170a in the shortcircuit ring 170 to deform in the manner described above and, therefore, the number of assembling steps can advantageously be reduced.

It is to be noted that where the permanent magnets is made of a rare earth metal of, for example, Nd-Fe-B system, a strong magnetic force can be obtained and, therefore, the rotor as well as the motor as a whole can be

manufactured in a compact size and lightweight.

It is also to be noted that in any one of the foregoing embodiments the rotor has been shown having two magnetic poles, it may have four or more magnetic poles. In addition, although in any one of the foregoing embodiments the single pole has been formed by abutting two plate-like permanent magnets of the same polarity in end-to-end fashion, the present invention may not be limited thereto and the single pole may be formed by the use of a single permanent magnet or three or more plate-like permanent magnets of the same polarity. Similarly, although the permanent magnets have been employed in the plate-like form, the present invention is not limited thereto and the present invention is equally applicable to the rotor employing permanent magnets of, for example, an arcuate shape or any other suitable shape.

Twenty-fourth Embodiment (Figs. 60 to 62)

A twenty-fourth preferred embodiment of the present invention will now be described with reference to Figs. 60 to 62, wherein Fig. 60 illustrates a longitudinal sectional view of the rotor used in the self-starting synchronous motor according to this embodiment, Fig. 61 is a transverse sectional view of the rotor shown in Fig. 60 and Fig. 62 is a fragmentary enlarged view showing an encircled portion indicated by 196 in Fig. 61.

Referring now to Figs. 60 to 62, reference numeral 181 represents a rotor, and reference numeral 182 represents a rotor iron core made of a laminate of electromagnetic steel plates. Reference numeral 183 represents conductor bars that are formed integrally together with shortcircuit rings 184, positioned at axially opposite ends of the rotor iron core 182, by the use of an aluminum die casting technique to form a starter squirrel cage conductor. Reference numeral 185 represents permanent magnets accommodated within magnet retaining holes 186, with each pair of plate-like permanent magnets 185 of the same polarity butted end-to-end in a generally V-shaped configuration to

form a single rotor magnetic pole. Since four permanent magnets 185 are employed in the rotor, two rotor magnetic poles are formed and, thus, the rotor as a whole has two magnetic poles.

A bridge portion indicated by 187 is so shaped as to have its width including a narrow portion 187a and a large-width portion 187b increasing in width in a direction radially outwardly from the narrow portion 187a. Shortcircuit of the magnetic fluxes between front and rear, opposite poles of the permanent magnets 185 can advantageously be prevented since magnetic saturation takes place at the narrow portion 187a.

Also, since an air space 188 is defined between each of respective end faces 185a of the neighboring permanent magnets 185 and the bridge portion 187, shortcircuit of the magnetic fluxes between the opposite poles within the end faces 185a of the neighboring permanent magnets 185 can advantageously be avoided.

Reference numeral 189 represents barrier slots for prevention of the magnetic flux shortcircuit that are defined between the neighboring permanent magnets 185 of the different polarities, which slots are filled up with aluminum injected during the aluminum die casting. A bridge portion 191 of the rotor iron core 182 between each barrier slot 189 and each magnet retaining hole 186 is so shaped as to have a small width, and at this bridge portion 191, magnetic saturation takes place to prevent the magnetic fluxes emanating from the opposite poles of the permanent magnets 185 from shortcircuiting. Also, an air space 192 is formed between an end face of each permanent magnet 185 and the adjacent bridge portion 191 to prevent the magnetic fluxes from the opposite poles within the end faces of the permanent magnets 185 from shortcircuiting. Reference numeral 193 represents an end plate made of a non-magnetizable material for protecting the permanent magnets 185. This end plate 193 is riveted to axially opposite end faces of the rotor iron core 182 by

means of rivet pins 194. Reference numeral 195 represents a bearing hole defined in the rotor.

According to the twenty-fourth embodiment, the rotor 181 can be assembled by embedding the permanent magnets 185 in the respective magnet retaining holes 186 after the starter squirrel cage conductor has been formed by the aluminum die casting in the rotor iron core 182 made of a laminate of the electromagnetic steel plates, and subsequently riveting the end plate 193 to each of the axially opposite end faces of the rotor iron core 182 by means of the rivet pins 194.

While after the aluminum die casting the shortcircuit rings will shrink in a radial direction during cooling of the aluminum, the rotor iron core 182 is also affected by a radially inwardly acting shrinkage stress. However, since the bridge portion 191 of the rotor iron core 182 is provided on each sides of each of the barrier slots 189 at a location adjacent the respective barrier slot 198 as shown in Fig. 58, a strength against the shrinkage stress is so high that circumferential shrinkage strains of an outer diameter of the rotor iron core 182 can be small.

On the other hand, since the bridge portion 187 is provided only at one location, strain acting in an inner diametric direction of the rotor iron core 182 at this portion is large. In order to avoid this, the length in a radial direction of the narrow portion 187a of the bridge portion 187 for prevention of the magnetic flux shortcircuit by magnetic saturation is reduced and, on the other hand, the large-width portion 187b is provided next to the narrow portion 187a, wherefore the strength against the radial shrinkage stress of the bridge portion 187 as a whole is made strong to prevent the strain from occurring in an inner diametric direction of the rotor iron core 182 at a location adjacent the bridge portion 187.

As such, the rotor iron core 182 can have an outer diameter of a

shape substantially similar to the right round shape and, therefore, if the outer diameter thereof is so chosen at the time of blanking the electromagnetic steel plates of the rotor iron core 182 that a gap between the outer diameter thereof and an inner diameter of the rotor iron core can be of a predetermined dimension, a step of grinding or milling the outer diameter of the rotor iron core after the aluminum die casting to provide the gap of the predetermined dimension can be dispensed with.

Although in any one of the foregoing embodiments the single pole has been formed by abutting two plate-like permanent magnets of the same polarity in end-to-end fashion, the present invention may not be limited thereto and the single pole may be formed by the use of a single permanent magnet or three or more plate-like permanent magnets of the same polarity. Similarly, although the permanent magnets have been employed in the plate-like form, the present invention is not limited thereto and the present invention is equally applicable to the rotor employing permanent magnets of, for example, an arcuate shape or any other suitable shape.

Thus, according to the twenty-fourth embodiment of the present invention, not only can any possible shortcircuit of the magnetic fluxes between the permanent magnet be prevented to secure a high performance, but also the grinding of the outer diameter of the rotor is eliminated, thereby making it possible to provide the high-performance, inexpensive self-starting synchronous motor.

Twenty-fifth Embodiment (Fig. 63)

Fig. 63 illustrates a plan view of an electromagnetic steel plate used to form the rotor in the self-starting synchronous motor according to this embodiment. Referring now to this figure, reference numeral 51 represents an electromagnetic steel plate, a plurality of which are laminated together to form the rotor iron core. After the rotor iron core has been so formed, the rotor iron

core is subjected to the aluminum die casting to form the starter squirrel cage conductor in the rotor iron core. Reference numeral 203 represents magnet retaining holes; reference numeral 204 represents a bridge portion F for each pair of the permanent magnets; reference numeral 205 represents barrier slots for prevention of shortcircuit of the magnetic fluxes; reference numeral 206 represents a bridge portion; reference numeral 207 represents rivet holes through which rivets are passed to secure the end plate to each axial end face of the rotor core; and reference numeral 208 represents a bearing hole. The permanent magnets to be inserted after the aluminum die casting are shown by double-dotted lines and the rotor has two rotor magnetic poles formed therein.

The electromagnetic steel plate 201 has an outer diameter that is set to an outer diameter R1 sufficient to allow a gap between the rotor and the inner diameter of the stator iron core at one end of the rotor to satisfy a predetermined dimension, which outer diameter R1 progressively increases towards a center point of the rotor magnetic pole so that the outer diameter R2 of the center portion of the rotor magnetic poles can be greater than the outer diameter R1. By blanking the electromagnetic steel plate of the above described shape and laminating a predetermined number of the electromagnetic steel plates to form the rotor iron core and after the starter squirrel cage conductor has been formed by the use of the aluminum die casting, the permanent magnets are mounted in the rotor iron core.

After the aluminum die casting, the shortcircuit rings (not shown) formed on the axially opposite end faces of the rotor iron core of the starter squirrel cage conductor undergo a shrinkage in a radial direction as they are cooled, accompanied by a radial shrinkage of the outer diameter of the rotor iron core under the influence of a shrinkage force of the shortcircuit rings.

At this time, since the rotor magnetic pole ends of the electromagnetic steel plates 201 of the rotor iron core have the bridge portion

206 defined at two locations, the strength is so high against the shrinkage stress in the inner diametric direction that the outer diameter R1 of the rotor iron core will not vary virtually. However, since at the center portion of the rotor magnetic poles the bridge portion 264 is defined only at one location, the strength is so low that the outer diameter R2 of the rotor iron core will shrink in a radial direction under the influence of the shrinkage stress. At this time, if the dimension of the outer diameter R2 is chosen to be R1 after shrinkage, the outer diameter of the rotor iron core as a whole can be maintained at a substantially round shape.

It is to be noted that although in Fig. 63 the circle of the outer diameter R1 after the shrinkage is shown by the double-dotted line, the difference in dimension between R1 and R2 are shown exaggerated to facilitate a better understanding.

Although in the foregoing embodiments the single pole has been formed by abutting two plate-like permanent magnets of the same polarity in end-to-end fashion, the present invention may not be limited thereto and the single pole may be formed by the use of a single permanent magnet or three or more plate-like permanent magnets of the same polarity.

According to the twenty-fifth embodiment of the present invention, since the outer diameter of the rotor iron core after the aluminum die casting attains a shape substantially similar to the right round shape, and since the gap between it and the inner diameter of the stator iron core can be formed by pre-blanking with the use of dies, there is no need to grind or mill the outer diameter of the rotor iron core and, therefore, the number of assembling steps can be reduced. Also, since the aluminum die casting is carried out while the permanent magnets and the end plates have not yet been fitted, the job can be easily performed with no defect parts occurring and, in view of those cumulative effect, the productivity can be increased.

Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.

CLAIMS

1. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars accommodated within corresponding slots defined in an outer peripheral portion of the rotor iron core, said conductor bars having their opposite ends shortcircuited by respective shortcircuit rings to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars; and

permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles;

the neighboring members of the slots being spaced a distance which is referred to as a slot interval, the slot interval at a location adjacent one end of rotor magnetic poles being smaller than the slot interval at a location adjacent a center point of the rotor magnetic poles.

2. The synchronous motor as claimed in Claim 1, wherein the slot interval at a location spaced from the center point of the rotor magnetic poles in a direction conforming to a direction of rotation of the rotor is chosen to be greater than the slot interval at a location spaced from the center point of the rotor magnetic poles in a direction counter to the direction of rotation of the rotor.

3. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a

plurality of conductor bars accommodated within corresponding slots defined in an outer peripheral portion of the rotor iron core, said conductor bars having their opposite ends shortcircuited by respective shortcircuit rings to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars; and

permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles;

said slots having a radial length that is smaller at a center point of the rotor magnetic poles; and

a distance between one of the slots positioned adjacent one end of the rotor magnetic poles and the magnet retaining holes being smaller than a distance between the slots positioned at other locations of the rotor and the magnet retaining holes.

4. The asynchronous motor as claimed in claim 3, wherein the distance between the slots in the rotor iron core and the magnet retaining holes progressively increases from a position adjacent one end of the rotor magnetic poles towards a position adjacent the center point of the rotor magnetic poles.

5. A synchronous motor which comprises:

a stator including a stator iron core having two-pole windings wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core, and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor having a plurality of magnet retaining slots defined therein at a location on an inner side of the conductor bars; and

permanent magnets embedded within the magnet retaining holes in the rotor and defining two magnetic poles of different polarities;

said shortcircuit rings having an inner diameter positioned outside the associated magnet retaining holes, the inner diameter of the shortcircuit rings at a location adjacent one end of the magnetic poles being chosen to be greater than an inner diametric dimension at a location adjacent the point intermediate of the magnetic poles.

6. The synchronous motor as claimed in Claim 5, wherein the inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted lies outside the magnet retaining holes in the rotor iron core;

wherein the inner diametric dimension of one of the shortcircuit rings adjacent one end of the magnetic poles is chosen to be greater than the inner diametric dimension thereof adjacent the point intermediate of the magnetic poles; and

wherein the inner diametric dimension of the other of the shortcircuit rings lies inwardly of the whole or a part of the magnet retaining holes; and

further comprising an end plate made of a non-magnetizable plate and positioned between such other shortcircuit ring and the rotor iron core so as to cover the magnet retaining holes.

7. The synchronous motor as claimed in Claim 5, wherein the inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted lies outside the magnet retaining holes in the rotor iron core;

wherein the inner diametric dimension of one of the shortcircuit rings adjacent one end of the magnetic poles is chosen to be greater than the inner diametric dimension thereof adjacent the point intermediate of the magnetic poles; and

wherein the inner diametric dimension of the other of the shortcircuit rings lies inwardly of the whole or a part of the magnet retaining holes; and

further comprising one or a plurality of electromagnetic steel plates of the rotor iron core adjacent the other shortcircuit ring, which is or are not formed with the magnet retaining holes.

8. The synchronous motor as claimed in Claim 5, wherein the inner diameter of the shortcircuit rings on one side where the permanent magnets are inserted is of a shape lying along the magnet retaining holes in the rotor iron core.

9. The synchronous motor as claimed in Claim 5, wherein the stator iron core is made up of a stator laminate of electromagnetic steel plates and the rotor iron core is also made up of a rotor laminate of electromagnetic steel plates, said stator laminate having a thickness about equal to that of the rotor laminate.

10. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core in the form of a rotor laminate of a plurality of electromagnetic steel plates and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor iron core including a magnet retaining portion provided with magnet retaining slots, a magnetic flux shortcircuit preventive portion coupled with the magnet retaining portion and provided with magnetic flux shortcircuit preventive holes communicated with the magnet retaining holes, and a rotor outer end portion coupled with the magnetic flux shortcircuit preventive portion and provided with holes communicated with the magnetic flux shortcircuit preventive holes; and

permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles;

said magnetic flux shortcircuit preventive holes being smaller than the magnet retaining holes such that by allowing the permanent magnets to be held

in engagement with outer edges of the magnetic flux shortcircuit preventive holes, the permanent magnets are axially positioned.

11. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core in the form of a rotor laminate of a plurality of iron plates and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor iron core including a magnet retaining portion provided with magnet retaining slots, and a permanent magnet support portion coupled with the magnet retaining portion and closing the magnet retaining holes; and

permanent magnets embedded within the magnet retaining holes in the rotor and defining rotor magnetic poles;

the permanent magnets being axially positioned by means of the permanent magnet support portion.

12. The synchronous motor as claimed in Claim 11, further comprising a rotor iron core outer end coupled with the permanent magnet support portion and provided with hole positioned axially of the magnet retaining holes.

13. The synchronous motor as claimed in Claim 10 or 11, further comprising a starter squirrel cage conductor in the rotor iron core.

14. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded

together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars, said magnet retaining holes having a width in a radial direction of the rotor iron core being greater at a location adjacent one end of the axial direction of the rotor than at a location inwardly of an axial direction of the rotor.

15. The synchronous motor as claimed in Claim 14, wherein the width of the magnet retaining holes in the radial direction is smaller at a location inwardly of the axial direction of the rotor than at opposite ends of the axial direction of the rotor and further comprising an electromagnetic steel plate provided outside one of the opposite ends of the axial direction of the rotor for closing the magnet retaining holes.

16. The synchronous motor as claimed in Claim 14, wherein the width of the magnet retaining holes in the radial direction is greater at one of opposite ends of the axial direction of the rotor than at a location inwardly of the axial direction of the rotor and wherein the other of the opposite ends of the axial direction of the rotor is not provided with any magnet retaining holes for closing the magnet retaining holes at a location inwardly of the axial direction of the rotor.

17. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor

iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars;

the rotor iron core being in the form of a laminate of electromagnetic steel plates and including an entwining portion provided adjacent the magnet retaining holes for lamination of the electromagnetic steel plates, wherein the magnet retaining holes adjacent the entwining portion has a width in a radial direction thereof which is partially enlarged in a direction towards the entwining portion.

18. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein; and

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars;

said rotor iron core having conductor bar holes defined therein in an axial direction thereof and positioned inwardly of the magnet retaining holes, said conductor bar holes being filled up by the aluminum die casting simultaneously

with the starter squirrel cage conductor, said conductor bars protruding a distance outwardly from an axial end of the rotor iron core to form respective projections for securement of an end plate, said end plate being made of a non-magnetizable material and secured fixedly to the end of the rotor iron core.

19. The synchronous motor as claimed in Claim 18, wherein the end plate disposed at the axial end of the rotor iron core is partly or wholly covered by the corresponding shortcircuit ring.

20. The synchronous motor as claimed in Claim 18, wherein the end plate covered by the shortcircuit ring is provided with projections engageable in respective holes in the rotor iron core.

21. The synchronous motor as claimed in Claim 18, wherein one or a plurality of electromagnetic steel plates at one axial end of the rotor iron core is or are not provided with any magnet retaining hole.

22. The synchronous motor as claimed in Claim 19, wherein at a location where the electromagnetic steel plates not provided with any magnet retaining holes contact the permanent magnets, there is provided projections protruding towards the permanent magnets.

23. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein, one of the shortcircuit rings having an inner periphery formed

with recesses;

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars; and

an end plate made of a non-magnetizable material and having an outer periphery formed with projections complemental in shape to the recesses in the shortcircuit ring, a peripheral portion of each of the recesses in the shortcircuit ring being axially pressed to deform to thereby secure the end plate to an axial end of the rotor iron core with the projections in the end plate received in the corresponding recesses in the shortcircuit ring.

24. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein;

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars;

said magnet retaining holes being of a design allowing the permanent magnets, when embedded therein so as to be butted end-to-end in a generally V-shaped configuration to form a single magnetic pole, and having an air space defined between one end face of the permanent magnet and an inner face of one end of the magnet retaining hole for preventing shortcircuit of magnetic fluxes, a barrier slot for preventing shortcircuit of magnetic fluxes being defined

between the magnet retaining holes for accommodating the neighboring permanent magnets of different polarities, a first bridge portion being provided between the magnet retaining hole and the barrier slot so as to sandwich the barrier slot, and a second bridge portion being provided between the neighboring permanent magnets of the same polarity and the corresponding magnet retaining holes, said second bridge portion being narrow at a location adjacent a center of the rotor and large at a location adjacent an outer periphery of the rotor.

25. A synchronous motor which comprises:

a stator including a stator iron core having a winding wound therearound, said stator iron core having an inner cylindrical surface;

a rotor including a rotor iron core and rotatably accommodated while facing the inner cylindrical surface of the stator iron core, said rotor including a plurality of conductor bars positioned adjacent an outer periphery of the rotor iron core and shortcircuit rings positioned at axially opposite ends of the rotor iron core, said conductor bars and said shortcircuit rings being integrally molded together by means of an aluminum die casting to form a starter squirrel cage conductor, said rotor iron core having a plurality of magnet retaining holes defined therein;

permanent magnets embedded within the magnet retaining holes at a location on an inner side of the conductor bars to provide two magnetic poles;

said rotor iron core increasing from axially opposite ends thereof towards a point intermediate of the length of the rotor to render it to represent a generally oval shape, the permanent magnets being mounted after formation of the starter squirrel cage conductor by means of the aluminum die casting.

26. A self-starting synchronous motor as claimed in any one of Claims 1 to 25, wherein the permanent magnets are employed in the form of a rare earth magnet.

Fig.1

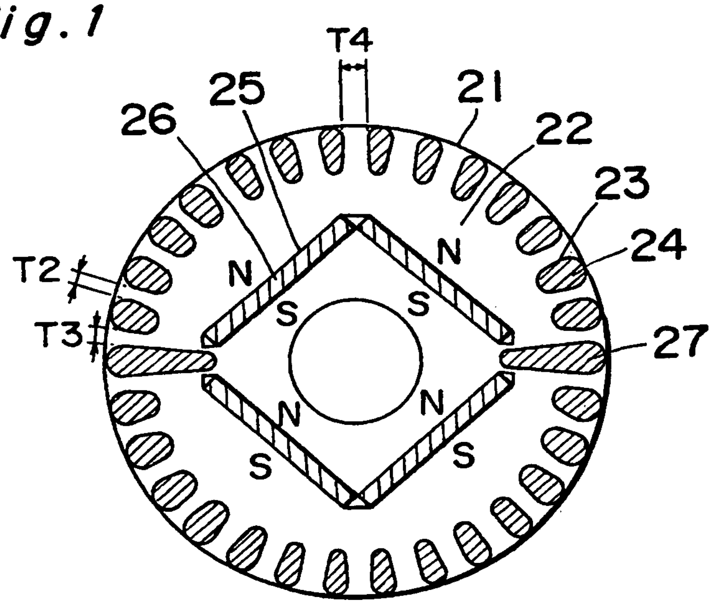

T4
21
25
26
22
23
24
T2
T3
27
N
S
N
S
N
N
S
S

Fig.2

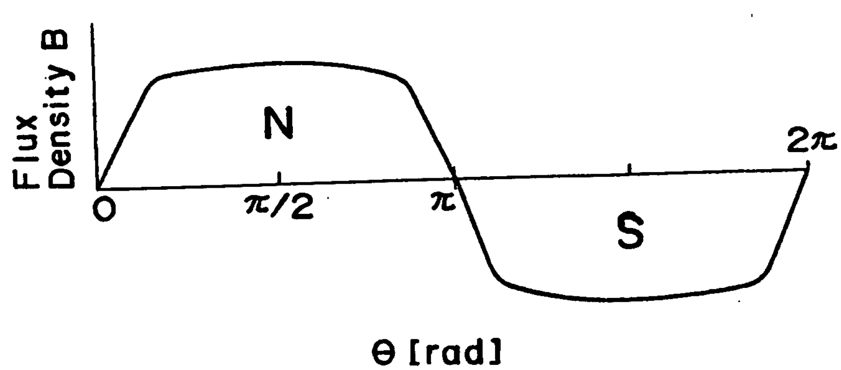

Flux Density B
N
S
0
π/2
π
2π
Θ [rad]

Fig.3

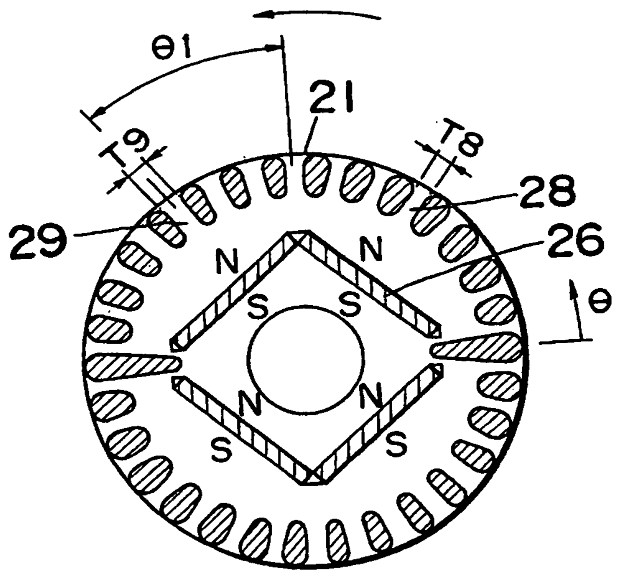


Fig.5

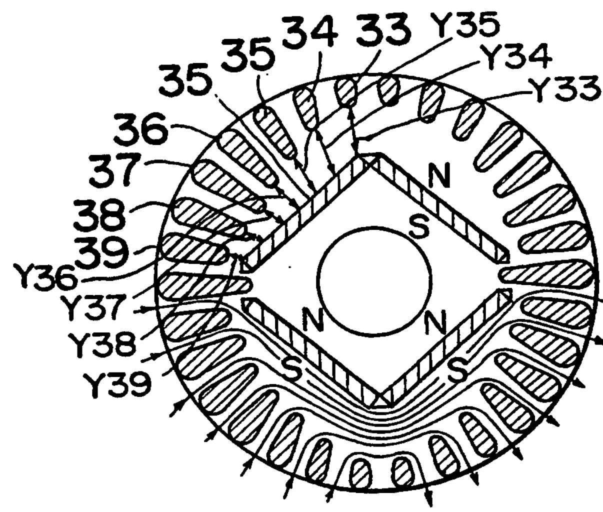


Fig.4

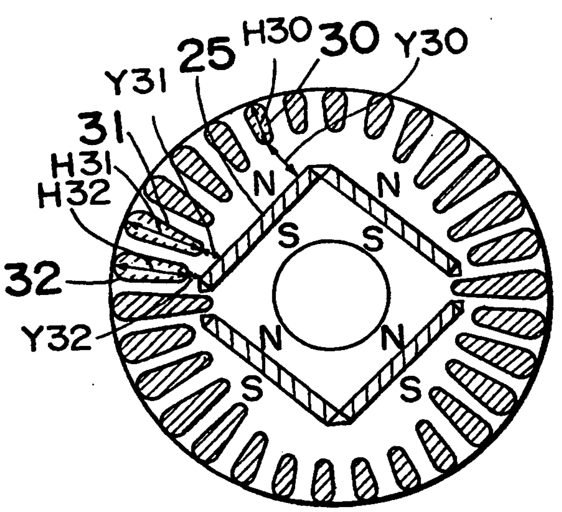


Fig.6

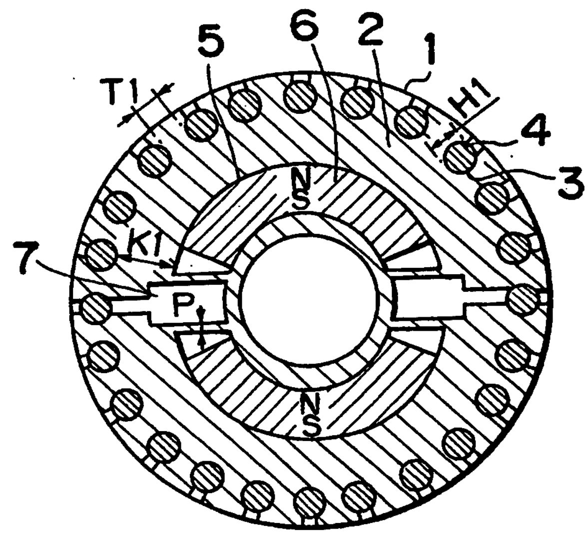


Fig.7

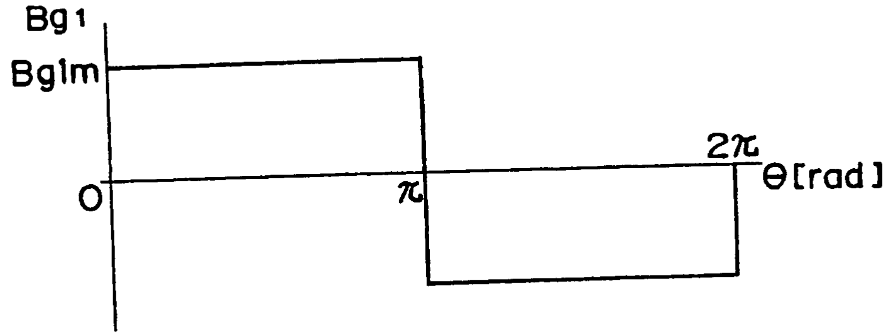


Fig.8

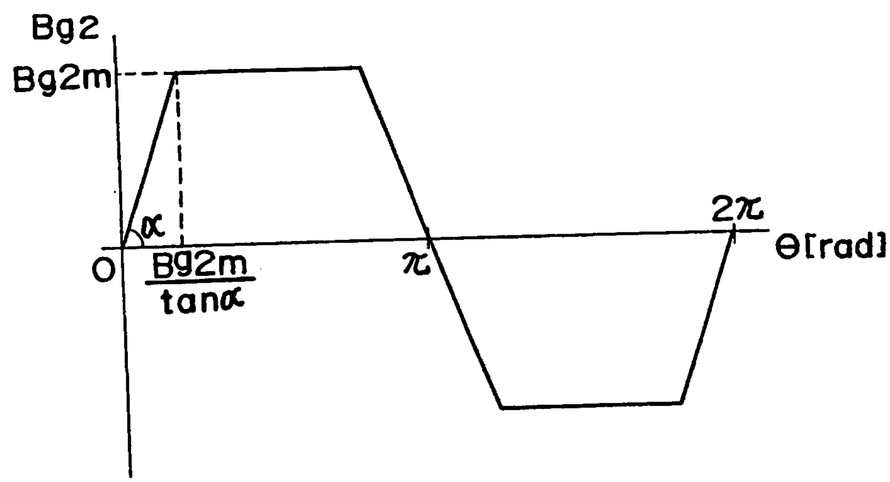


Fig.9

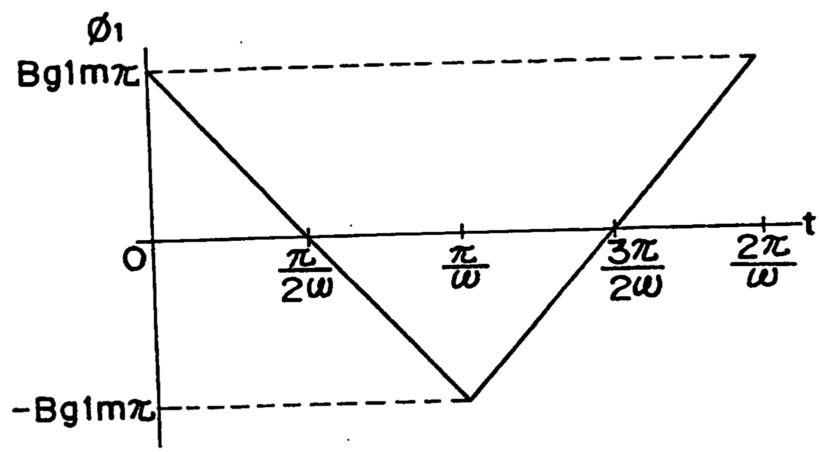


Fig.10

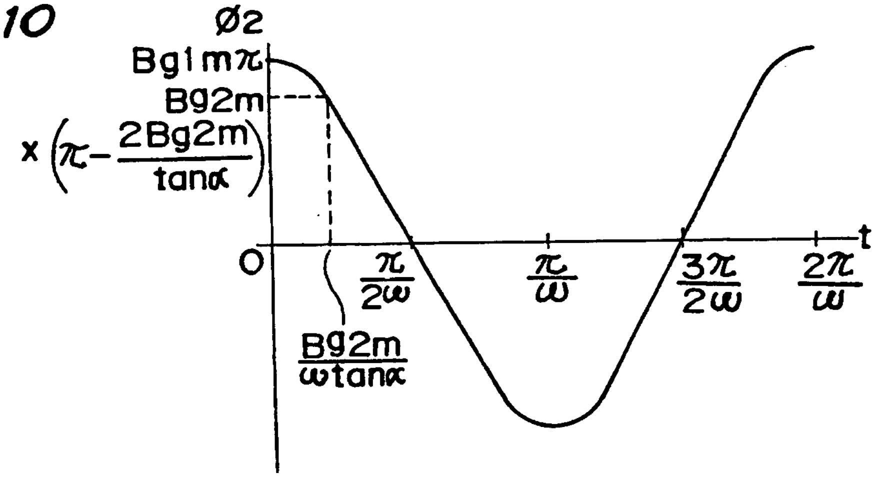


Fig.11

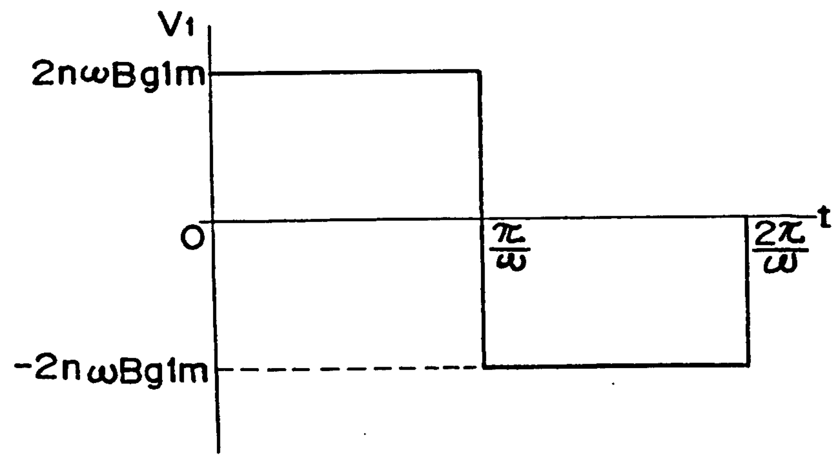


Fig.12

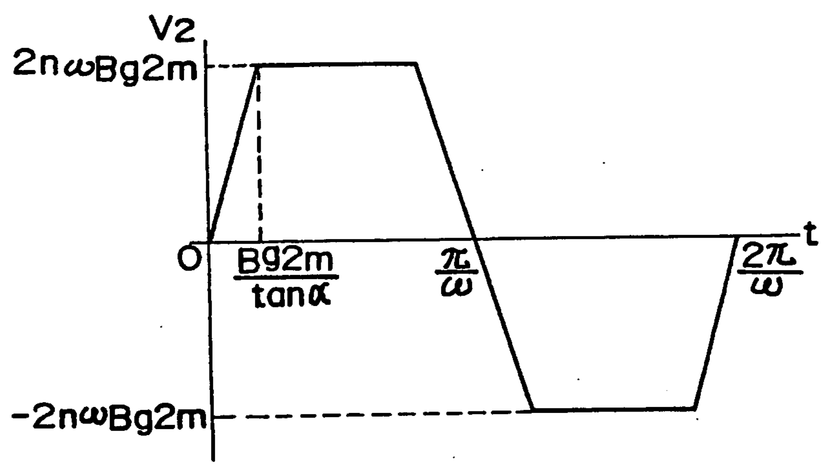


Fig. 13

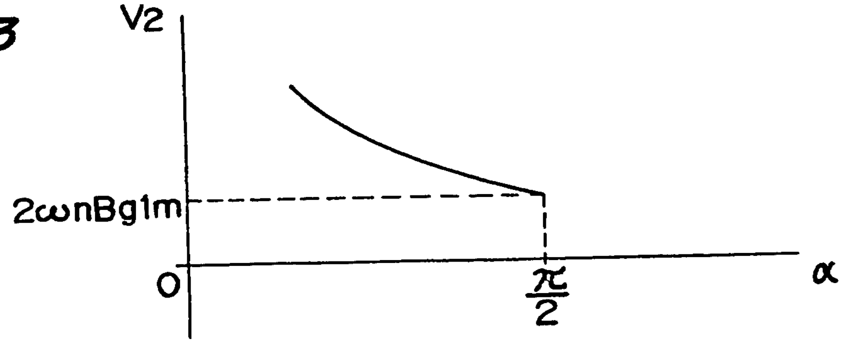


Fig. 14

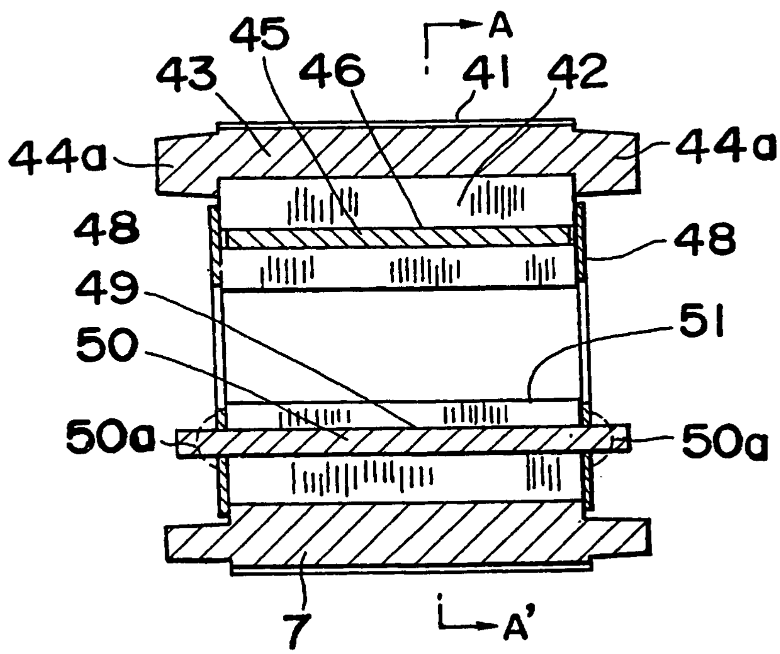


Fig. 16

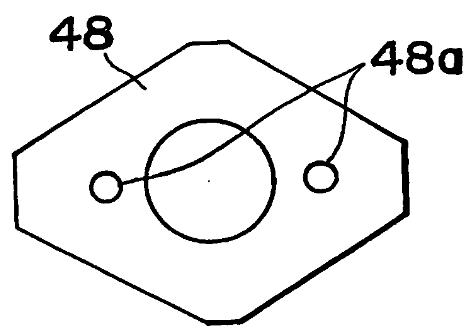


Fig.15

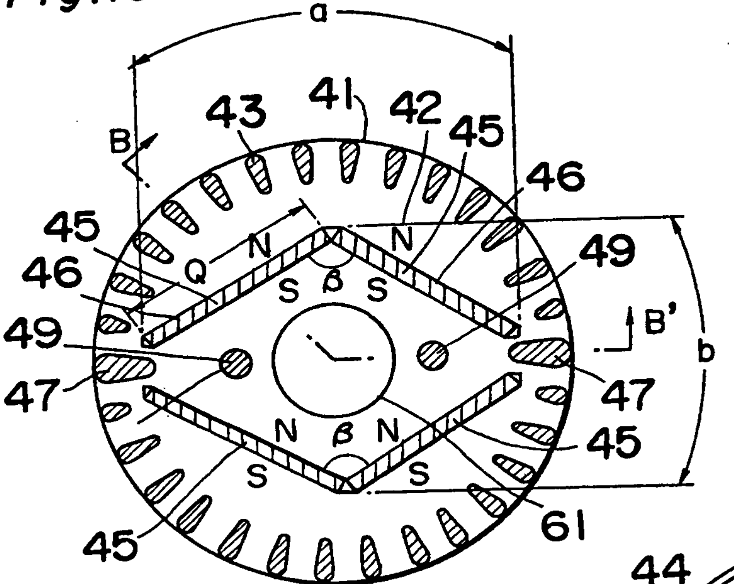


Fig.17

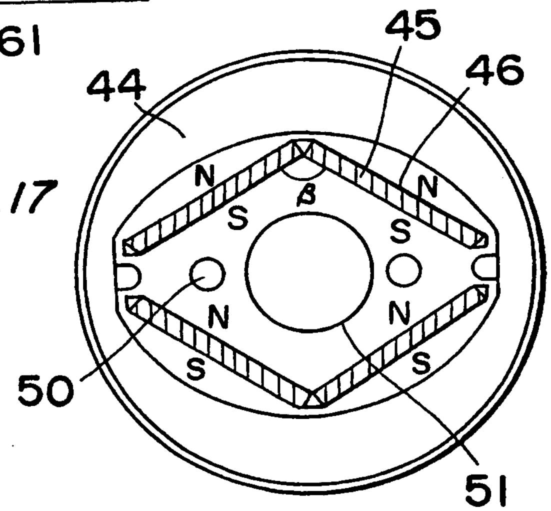


Fig.18

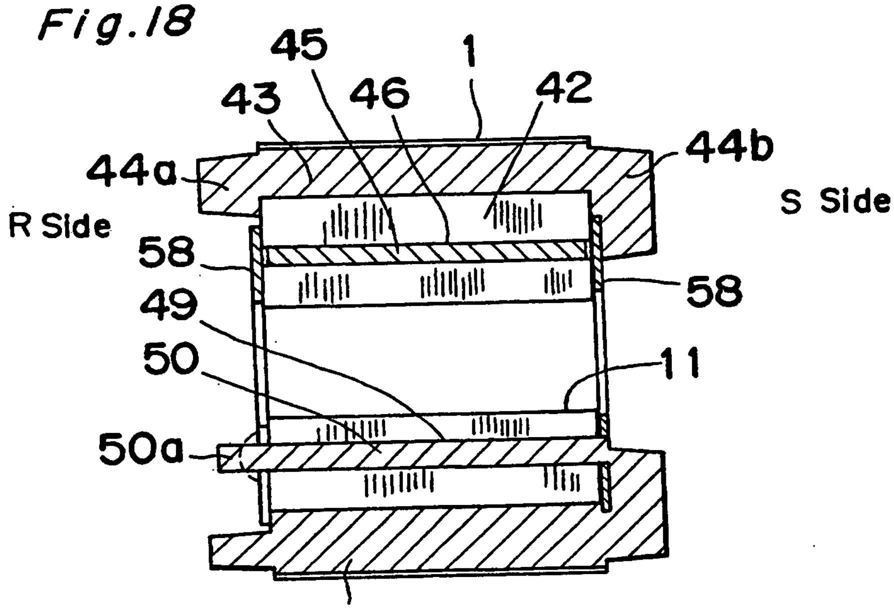


Fig.19

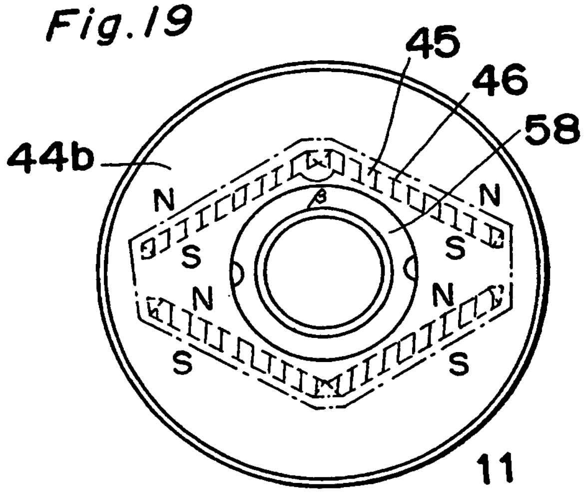


Fig.21

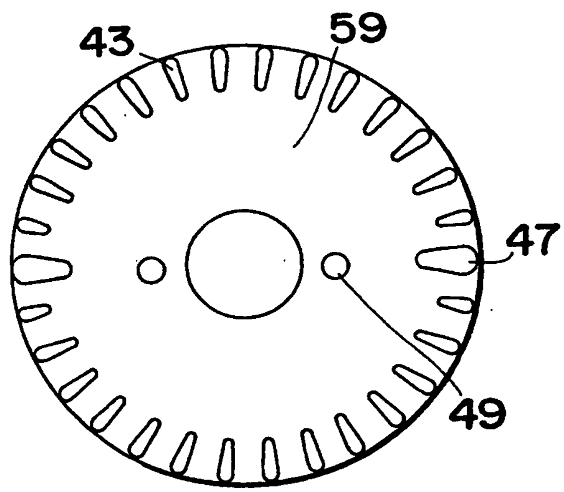


Fig.20

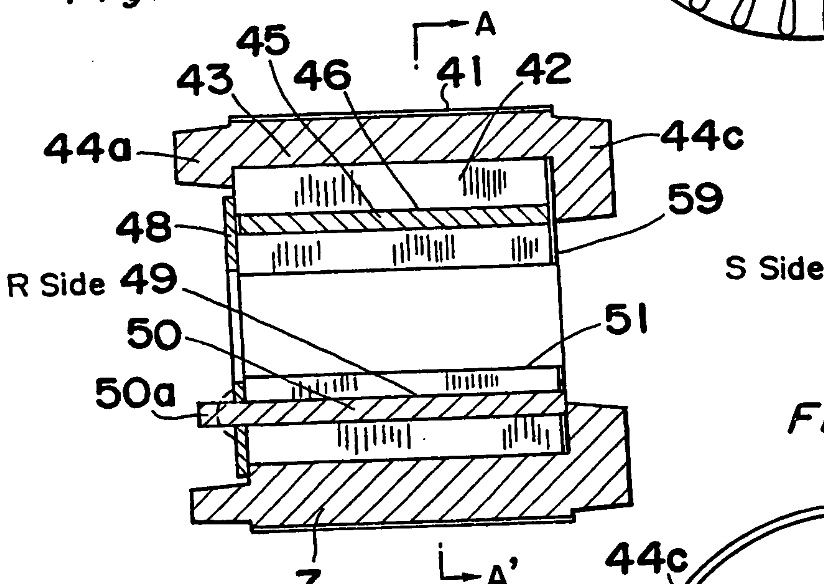


Fig.22

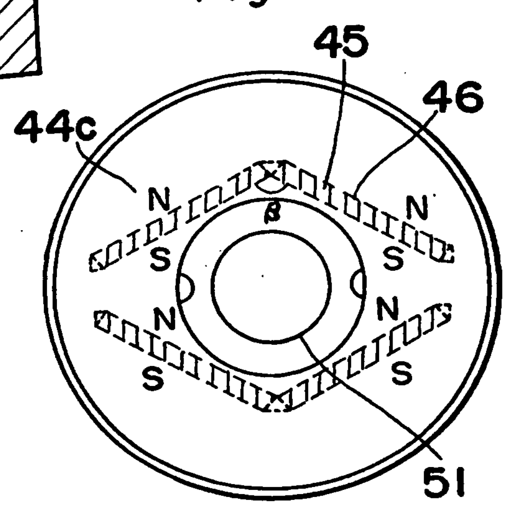


Fig.23

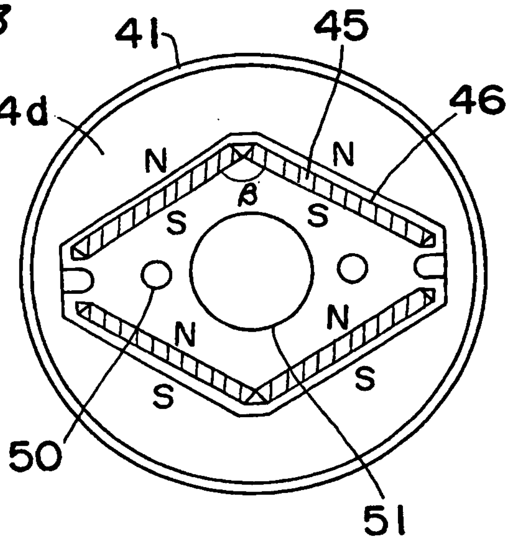


Fig.24

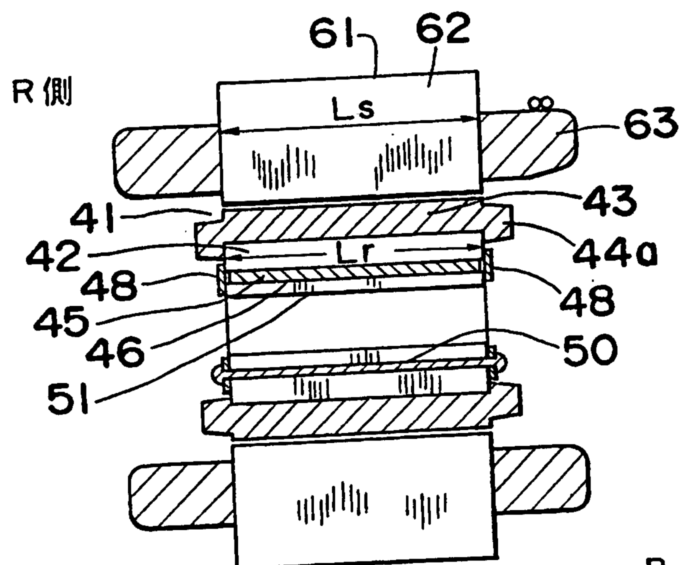


Fig.25

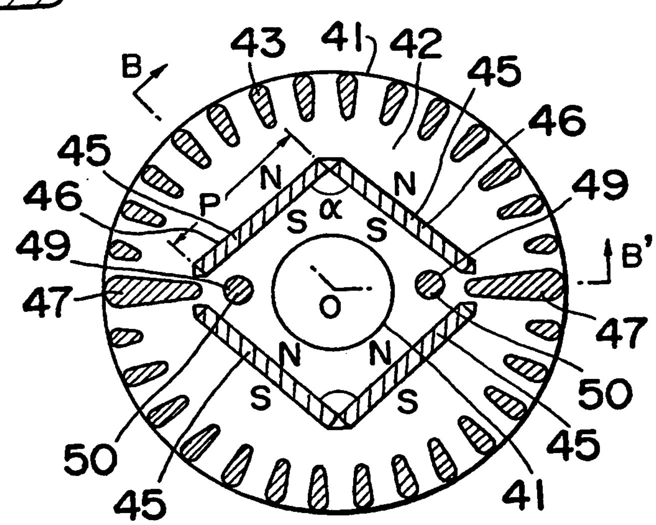


Fig.26

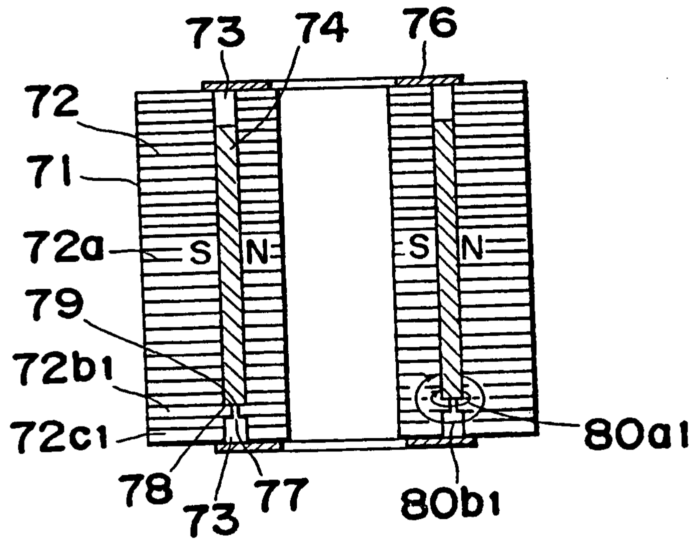


Fig.27

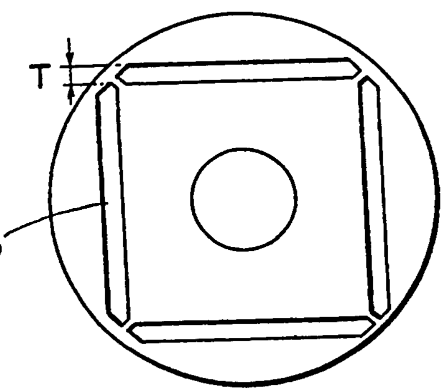


Fig.28

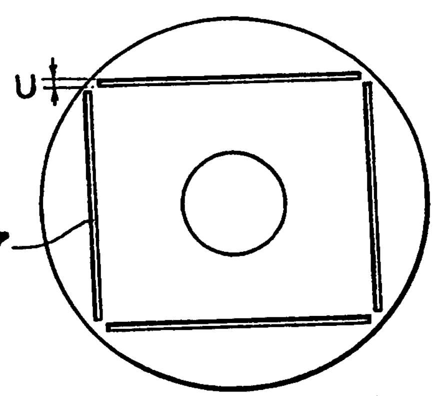


Fig.29

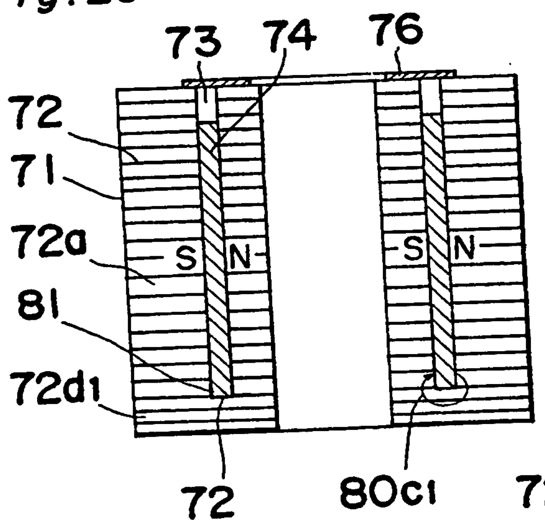


Fig.30

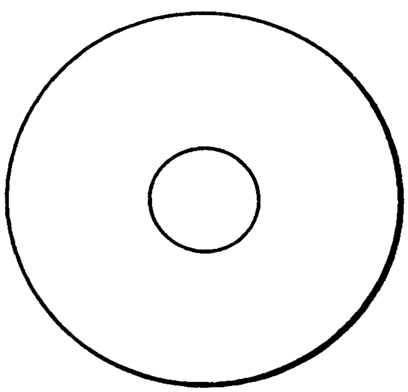


Fig.31

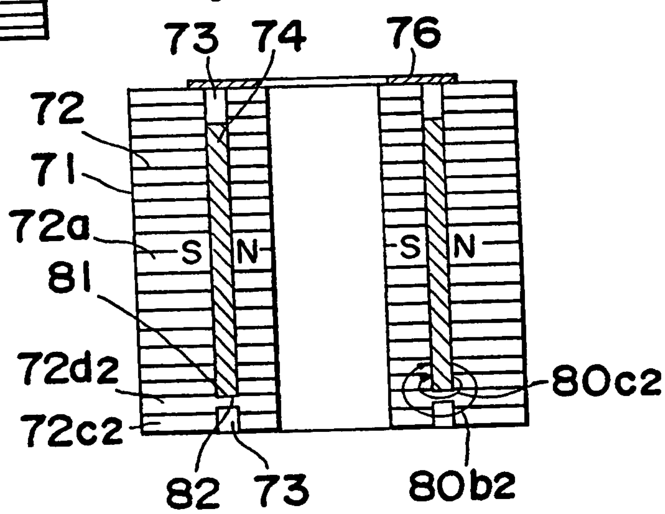


Fig.32

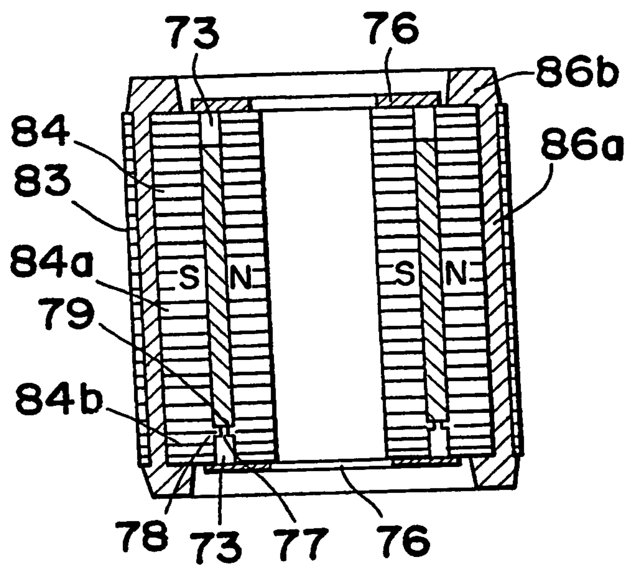


Fig.33

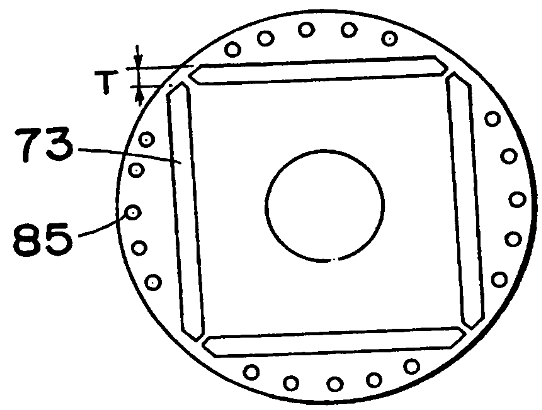


Fig.34

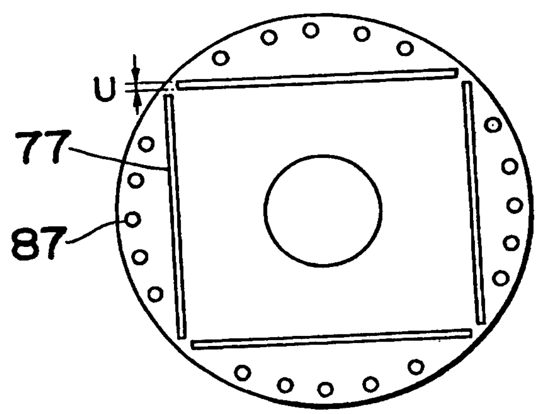


Fig.35

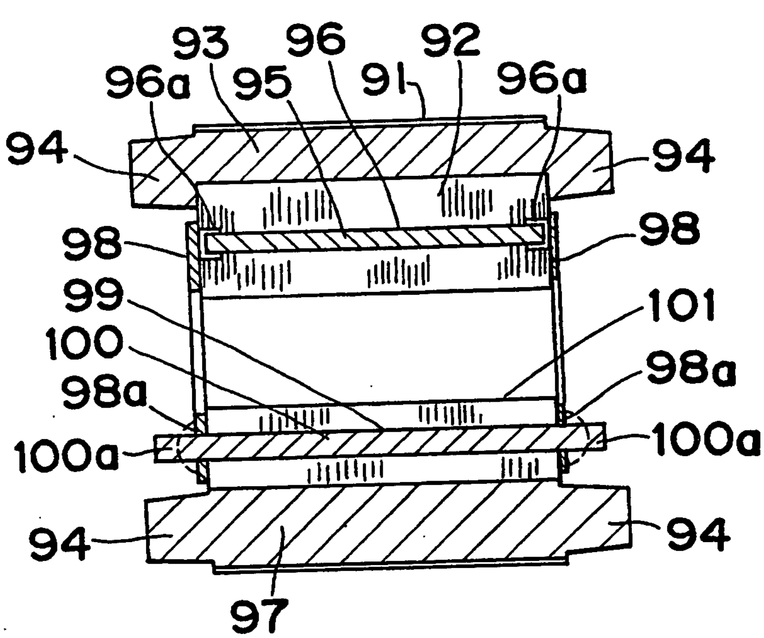


Fig.36

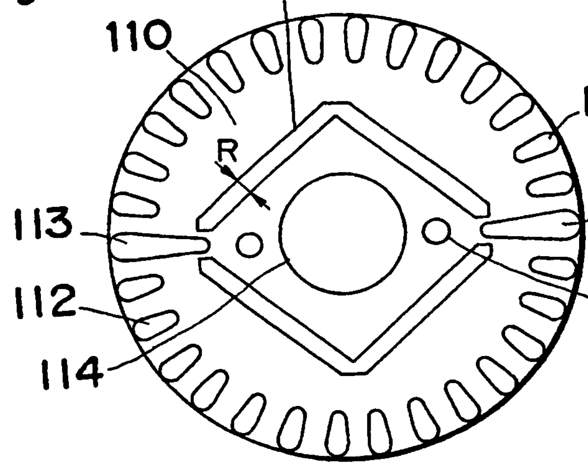


Fig.37

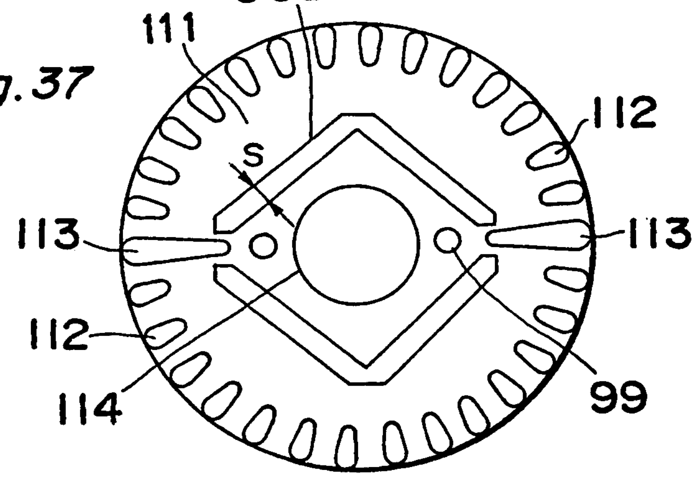


Fig.38

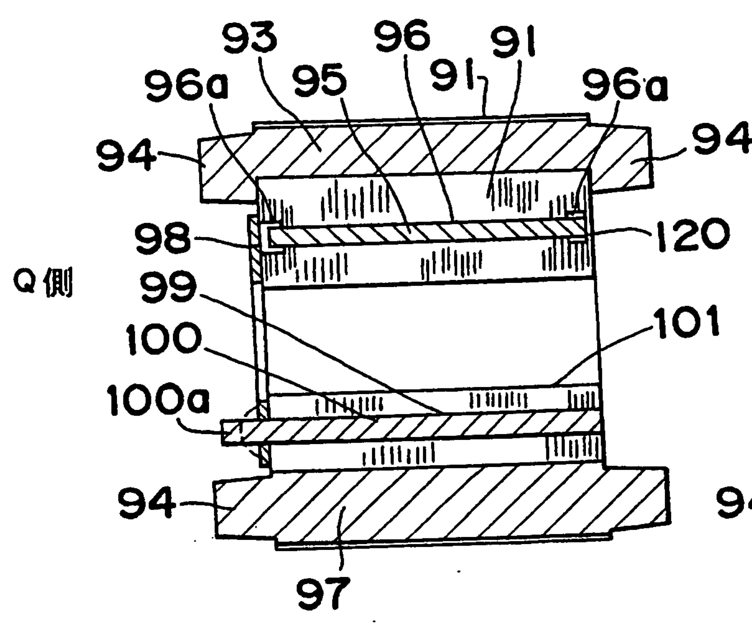


Fig.40

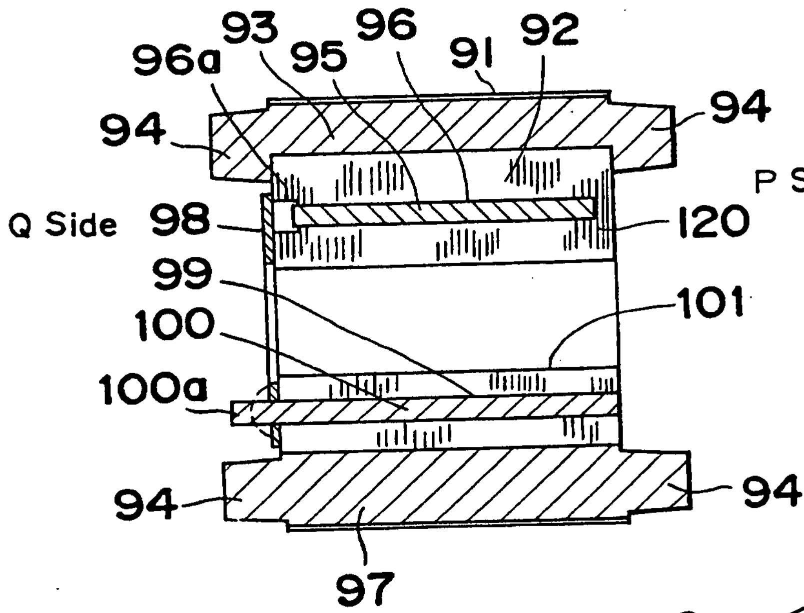


Fig.39

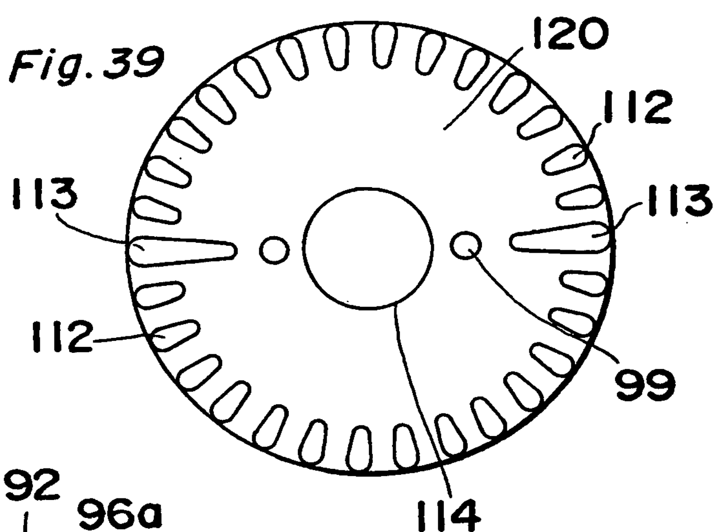


Fig.41

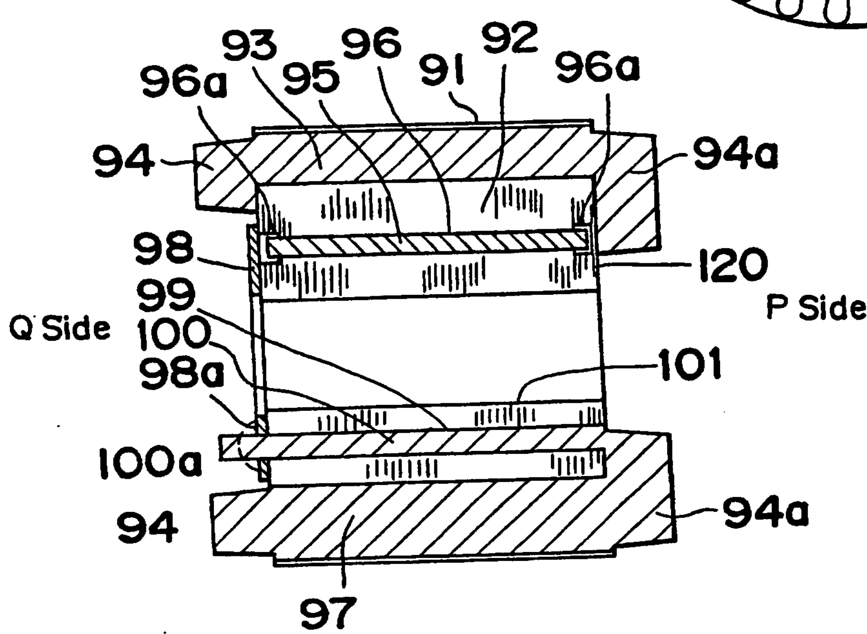


Fig.42

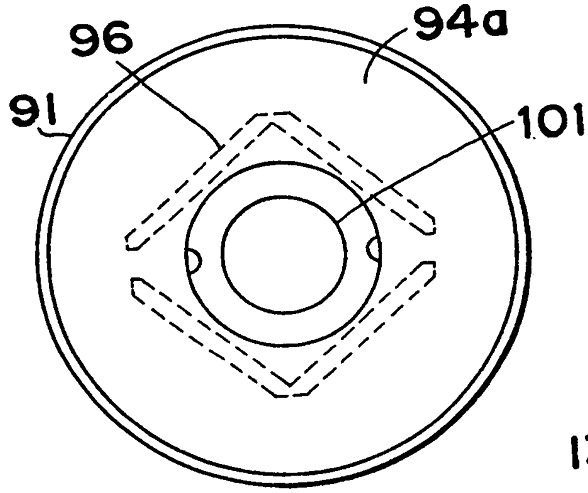


Fig.43

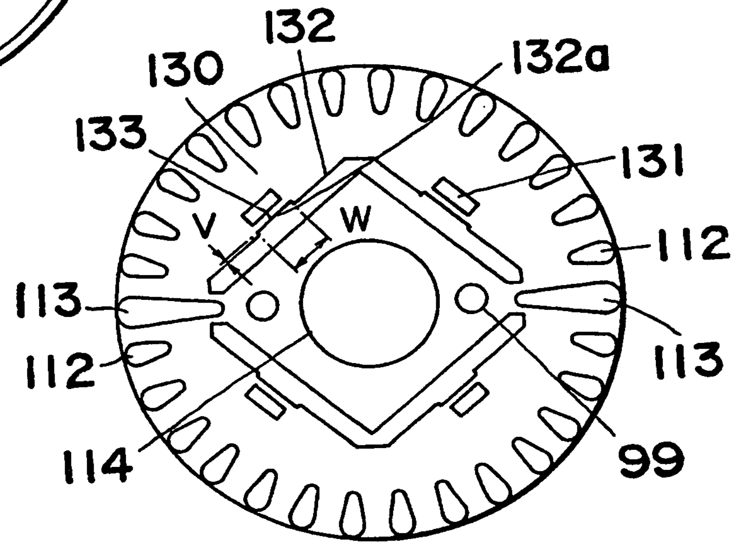


Fig.44

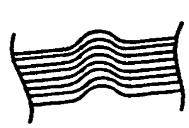


Fig.45

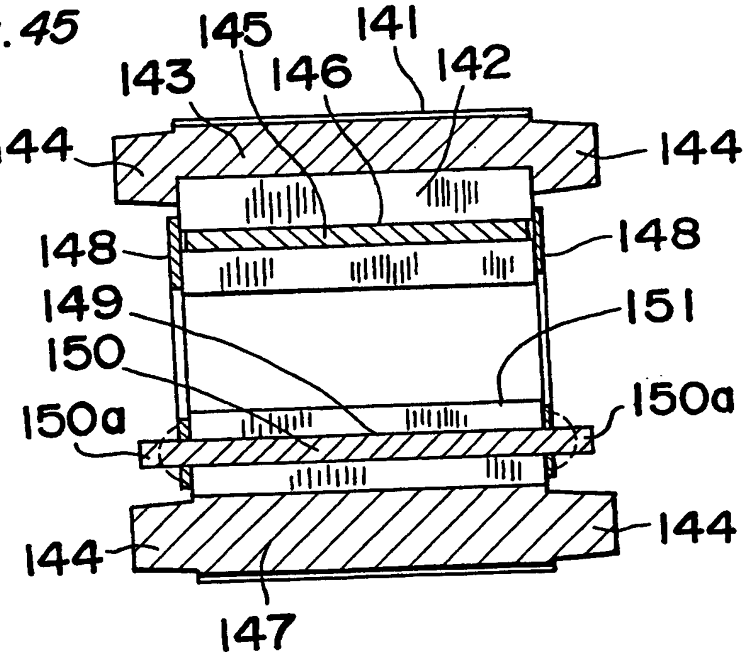


Fig.46

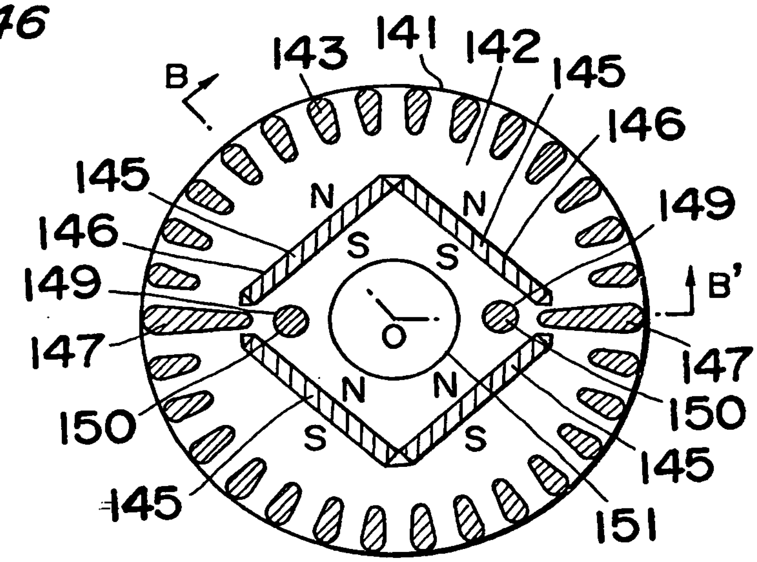


Fig.47

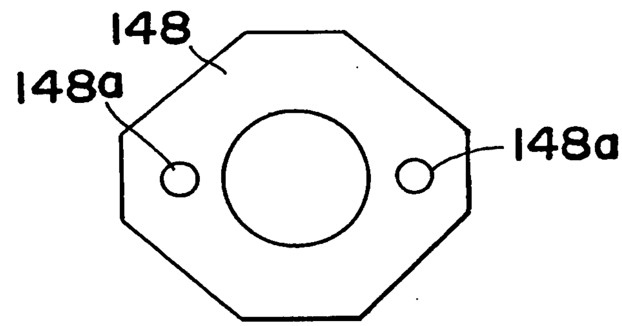


Fig.48

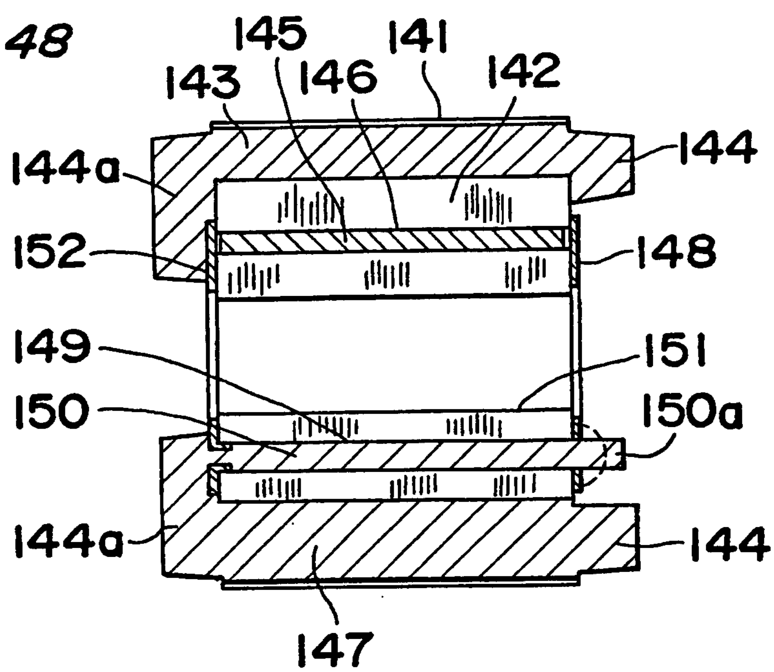


Fig. 49

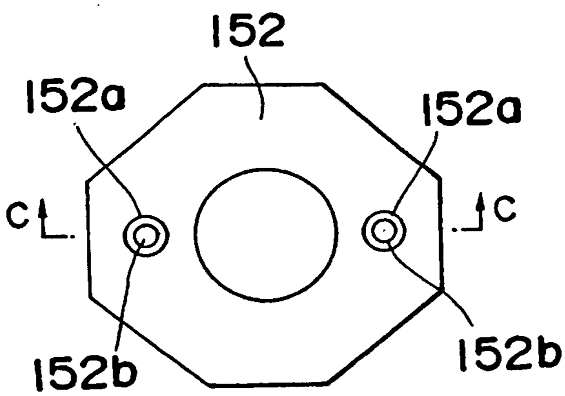


Fig. 50

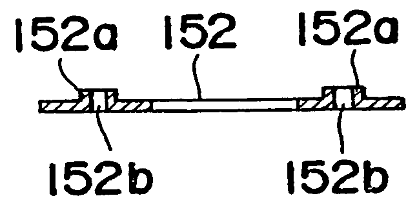


Fig. 51

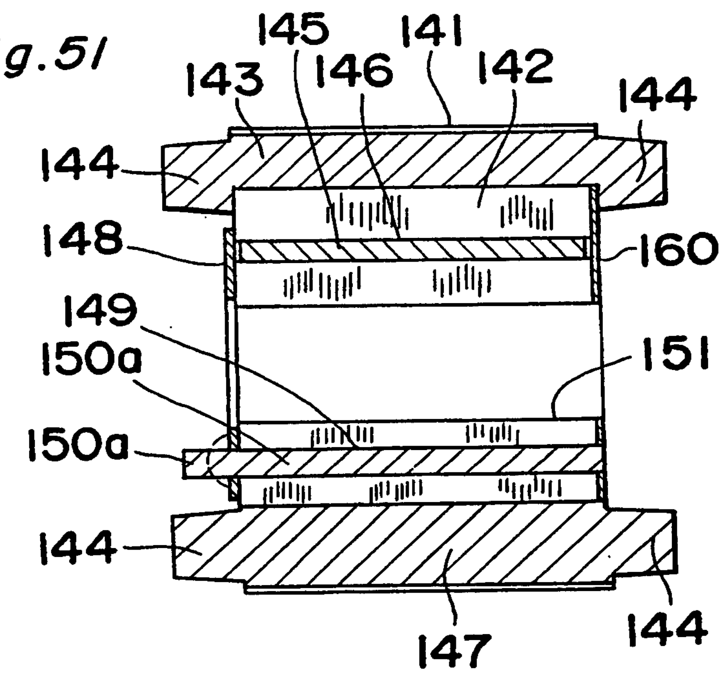


Fig. 52

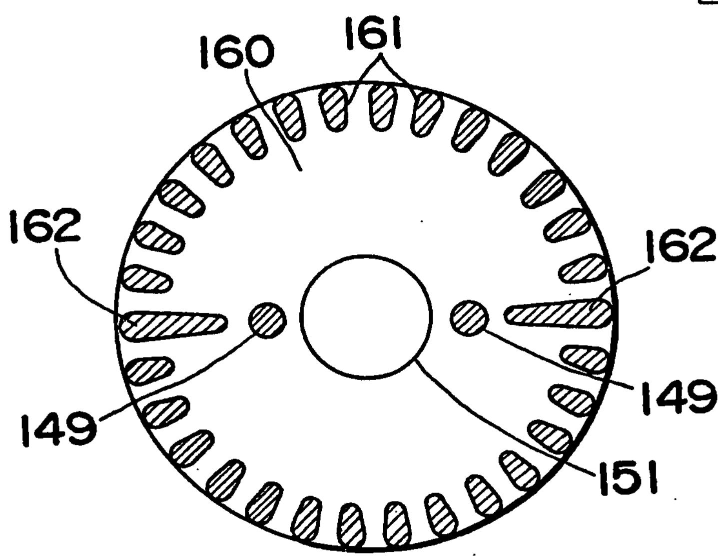


Fig.53

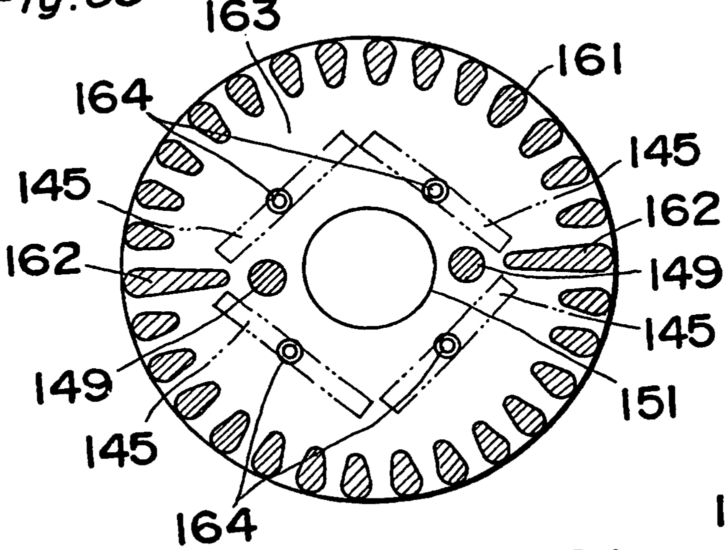


Fig.54

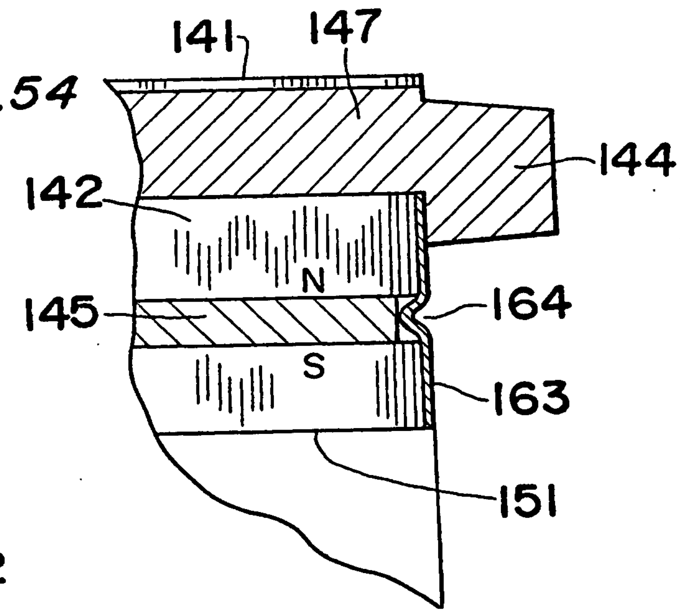


Fig.55

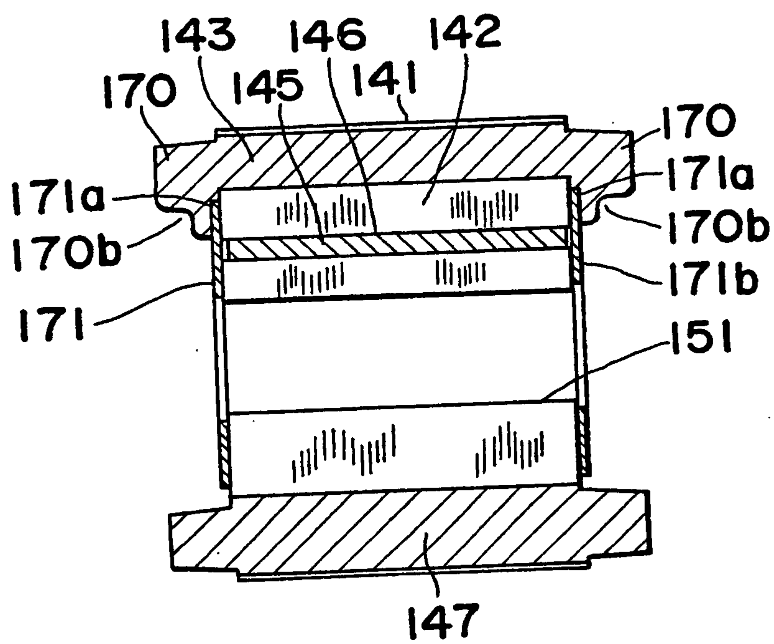


Fig.56

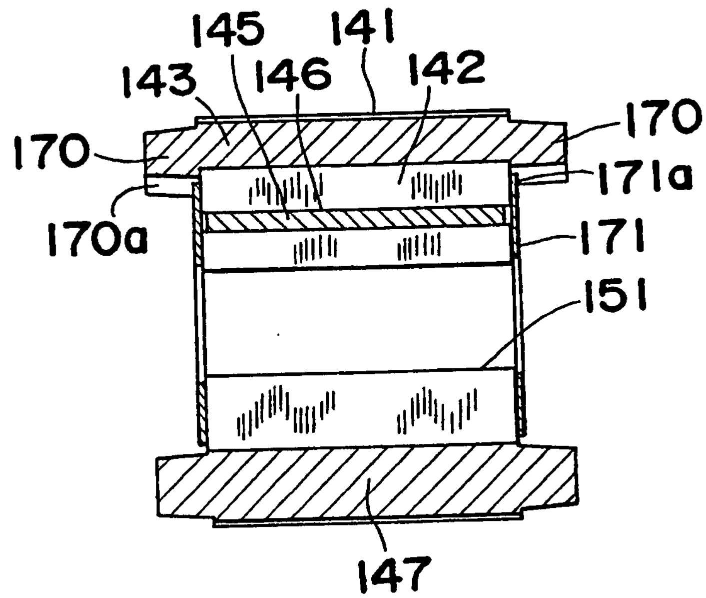


Fig.57

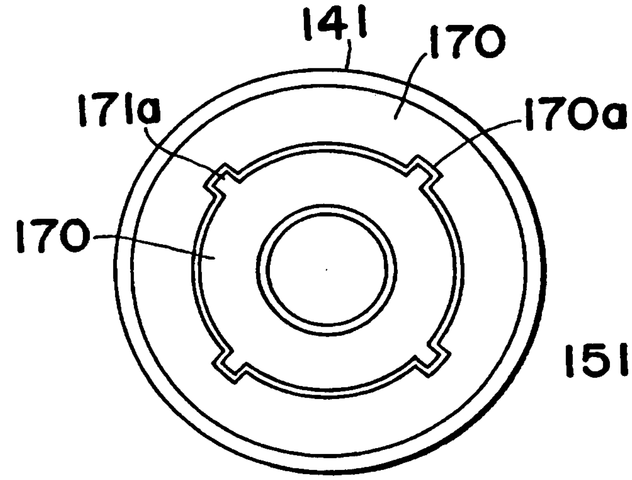
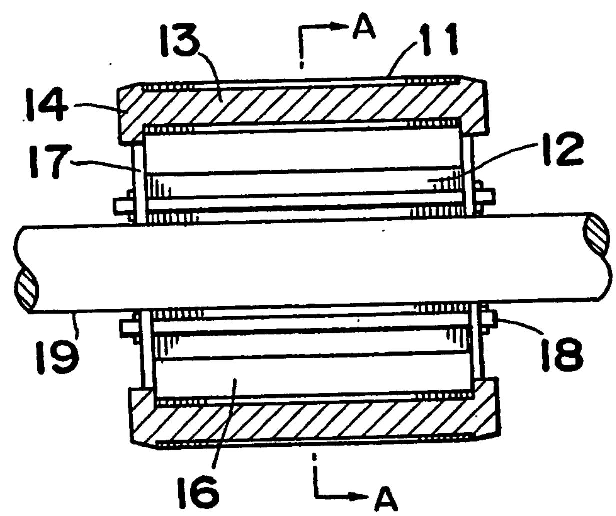


Fig.58



19/20

Fig.59

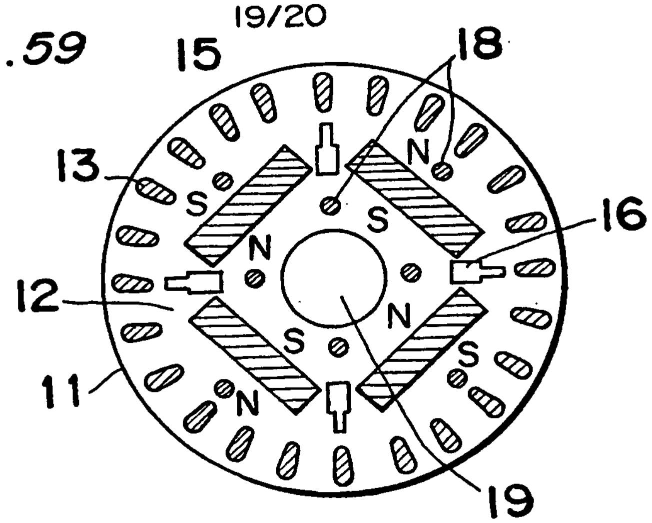


Fig.60

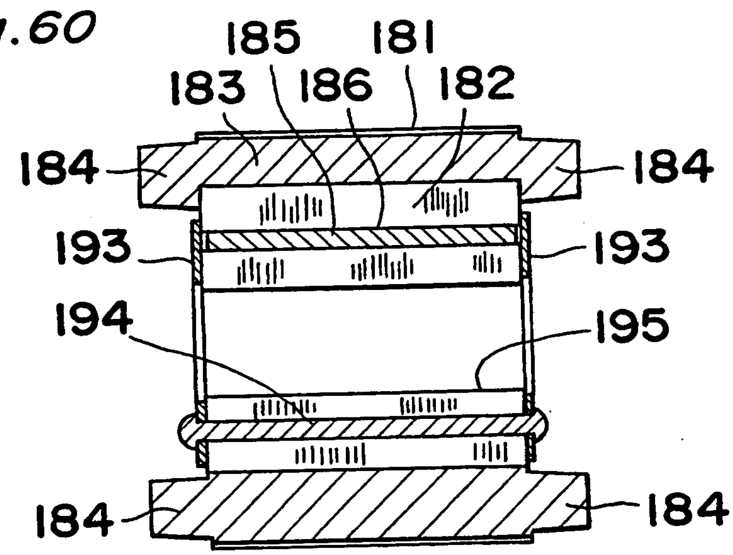


Fig.61

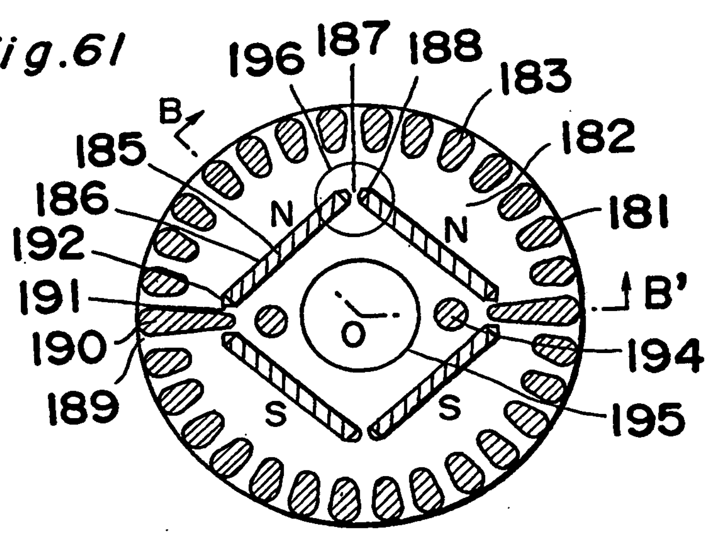
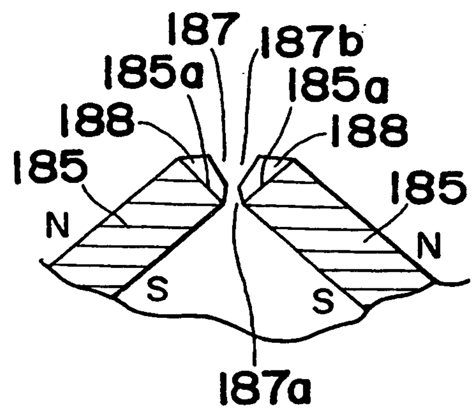


Fig.62


187
187b
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185a
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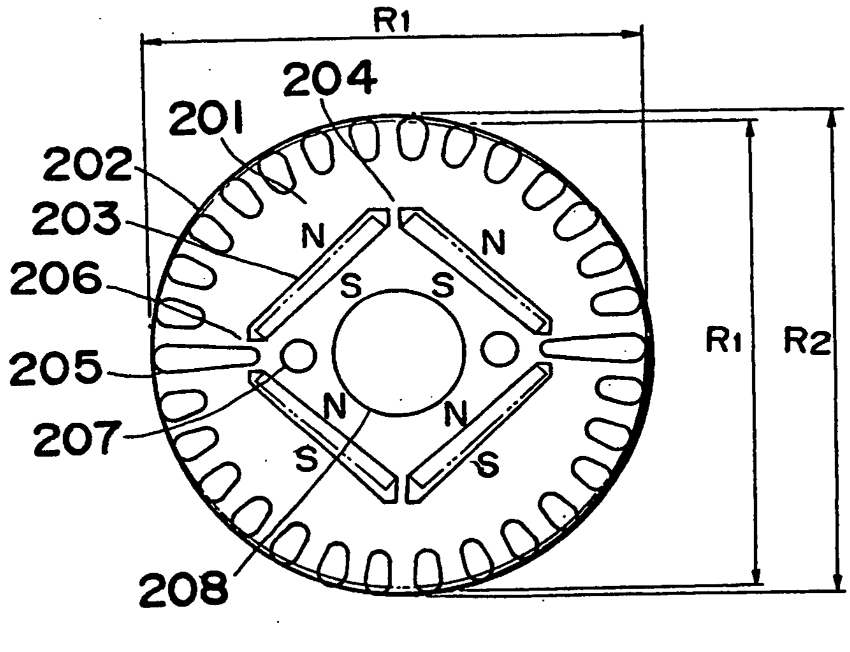
187a

Fig.63


R1
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208
N
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S
N
N
S
S
R1
R2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/04693

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02K21/46 H02K1/27

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1 552 694 A (CEM COMP ELECTRO MEC) 19 September 1979 (1979-09-19) figure 1 ---	
A	CH 458 510 A (SIEMENS AG) 30 August 1968 (1968-08-30) figures 2,3 ---	
A	US 4 322 648 A (RAY GLEN ET AL) 30 March 1982 (1982-03-30) column 3, line 46 -column 3, line 60 ---	
A	US 5 097 166 A (MIKULIC KRESO) 17 March 1992 (1992-03-17) figure 4 ---	
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 2000	06/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ramos, H

4

INTERNATIONAL SEARCH REPORT

Interna' 'l Application No
PCT/JP 00/04693

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 352 573 A (SIEMENS AG) 31 January 1990 (1990-01-31) figure 3 -----	

4

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

I.   rmation on patent family members

International Application No
PCT/JP 00/04693

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 1552694 A	19-09-1979	FR 2324150 A	08-04-1977
		CH 607432 A	15-12-1978
		DE 2621301 A	09-12-1976
		IT 1063215 B	11-02-1985
CH 458510 A		NONE	
US 4322648 A	30-03-1982	CA 1135761 A	16-11-1982
US 5097166 A	17-03-1992	CA 2051752 A,C	25-03-1992
EP 0352573 A	31-01-1990	JP 2079737 A	20-03-1990
		US 4922152 A	01-05-1990

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 30 January 2001 (30.01.01)	
International application No. PCT/JP00/04693	**Applicant's or agent's file reference** 662015
International filing date (day/month/year) 13 July 2000 (13.07.00)	**Priority date** (day/month/year) 16 July 1999 (16.07.99)
Applicant SASAKI, Kenji et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

10 January 2001 (10.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Antonia Muller Telephone No.: (41-22) 338.83.38

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PATENT COOPERATION TREATY

PCT

RCVD 23 AUG 2001

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 662015	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/JP00/04693	International filing date *(day/month/year)* 13/07/2000	Priority date *(day/month/year)* 16/07/1999
International Patent Classification (IPC) or national classification and IPC H02K21/46		
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand 07/12/2000	Date of completion of this report 21.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Drysdale, N Telephone No. +49 89 2399 2435

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-63 as originally filed

Claims, No.:

1-26 as originally filed

Drawings, sheets:

1/20-20/20 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-26
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-26
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-26
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

V. Reasoned statement

2. Citations and explanations

1. Reference is made to the following documents cited in the international search report:

   D1 = US 5 097 166.

2. Out of a total of 26 claims, the present application includes 11 independent claims in the same category, viz.
   Nos. 1, 3, 5, 10, 11, 14, 17, 18, 23, 24, 25.

   Although these claims have been drafted as separate independent claims, several groups appear to relate effectively to the same subject-matter, the individual claims differing from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

   Hence, the claims now on file do not meet the requirements of Article 6 PCT.

   In order to overcome this objection, it would have been appropriate to file an amended set of claims defining the relevant subject-matter in terms of a minimum number of independent claims in each category followed by dependent claims covering features which are merely optional (Rule 6.4 PCT).

3. In view of the above objection it is not at present possible to carry out a proper substantive examination. However, it appears that the most relevant available document is D1, and that it provides no basis for objection to the claims on file on grounds of lack of novelty or inventive step. This conclusion is, however, provisional.

VII. Certain defects

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

VIII. Certain observations

1. The claims are not clear in several respects (Art. 6 PCT). In several claims reference is made to slots for conductor bars, slots for permanent magnets and "slots". In most, if not all, cases it appears that the "slots" are conductor bar slots, and this should be made clear.

2. The second paragraphs of claims 6 and 7 appear to be redundant, as they are already included in claim 5, on which these claims depend.

3. Claim 5 concerns details of the short-circuit rings. However, these details, apparently shown in Fig. 17, appear to be made necessary by the arrangement of the permanent magnets shown in Fig. 15 (cf. description, page 33, line 11 to page 34, line 6), yet this arrangement is not described in claim 5. Independent claim 5 does not, therefore, appear to include all the essential technical features necessary to define the invention (Art. 6 PCT).

4. It is not clear what, if any, is the difference between the "third embodiment" (page 29, Fig. 4) and the "fourth embodiment" (Fig. 5, page 30).

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

受付
12. 9. 8
青山特許事務所

To:

AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540-0001
JAPON

Date of mailing (day/month/year)	**IMPORTANT NOTIFICATION**
18 August 2000 (18.08.00)	
Applicant's or agent's file reference 662015	**International application No.** PCT/JP00/04693

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al (for all designated States except US)
SASAKI, Kenji et al (for US)

International filing date : 13 July 2000 (13.07.00)

Priority date(s) claimed :
16 July 1999 (16.07.99)
16 July 1999 (16.07.99)
10 September 1999 (10.09.99)
27 September 1999 (27.09.99)
01 June 2000 (01.06.00)
01 June 2000 (01.06.00)

Date of receipt of the record copy by the International Bureau : 28 July 2000 (28.07.00)

List of designated Offices :

AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
National :AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CR,CU,CZ,DE,DK,DM,DZ,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,KE,KG,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,US,UZ,VN,YU,ZA,ZW

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer: Masashi HONDA
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

003473824
外国方式

Continuation of Form PCT/IB/301

NOTIFICATION OF RECEIPT OF RECORD COPY

Date of mailing (day/month/year) 18 August 2000 (18.08.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 662015	International application No. PCT/JP00/04693

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [X] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

AOYAMA & PARTNERS
Attn. AOYAMA, Tamotsu
IMP Building, 3-7, Shiromi
1-chome, Chuo-ku, Osaka-shi
Osaka 540-0001
JAPAN

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

受付 12.11.6 青山特許事務所

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 06/11/2000
Applicant's or agent's file reference 662015	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/JP 00/ 04693	International filing date *(day/month/year)* 13/07/2000
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jacobus Constant

Form PCT/ISA/220 (July 1998)

外国方式

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 662015	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/JP 00/04693	International filing date *(day/month/year)* 13/07/2000	(Earliest) Priority Date *(day/month/year)* 16/07/1999
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
      - [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :
      - [ ] contained in the international application in written form.
      - [ ] filed together with the international application in computer readable form.
      - [ ] furnished subsequently to this Authority in written form.
      - [ ] furnished subsequently to this Authority in computer readble form.
      - [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      - [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).
4. With regard to the **title**,
   - [X] the text is approved as submitted by the applicant.
   - [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   - [X] the text is approved as submitted by the applicant.
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1
   - [X] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/04693

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02K21/46 H02K1/27

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1 552 694 A (CEM COMP ELECTRO MEC) 19 September 1979 (1979-09-19) figure 1	
A	CH 458 510 A (SIEMENS AG) 30 August 1968 (1968-08-30) figures 2,3	
A	US 4 322 648 A (RAY GLEN ET AL) 30 March 1982 (1982-03-30) column 3, line 46 -column 3, line 60	
A	US 5 097 166 A (MIKULIC KRESO) 17 March 1992 (1992-03-17) figure 4	

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 2000	06/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ramos, H

4

International Application No
PCT/JP 00/04693

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 352 573 A (SIEMENS AG) 31 January 1990 (1990-01-31) figure 3 -----	

4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP 00/04693

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 1552694 A	19-09-1979	FR 2324150 A	08-04-1977
		CH 607432 A	15-12-1978
		DE 2621301 A	09-12-1976
		IT 1063215 B	11-02-1985
CH 458510 A		NONE	
US 4322648 A	30-03-1982	CA 1135761 A	16-11-1982
US 5097166 A	17-03-1992	CA 2051752 A,C	25-03-1992
EP 0352573 A	31-01-1990	JP 2079737 A	20-03-1990
		US 4922152 A	01-05-1990

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

受付 12.11.13 青山特許事務所

To:

AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540-0001
JAPON

Date of mailing (day/month/year) 06 November 2000 (06.11.00)	
Applicant's or agent's file reference 662015	**IMPORTANT NOTIFICATION**
International application No. PCT/JP00/04693	International filing date (day/month/year) 13 July 2000 (13.07.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 16 July 1999 (16.07.99)
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An asterisk(*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
16 July 1999 (16.07.99)	11/203080	JP	03 Octo 2000 (03.10.00)
16 July 1999 (16.07.99)	11/203081	JP	03 Octo 2000 (03.10.00)
10 Sept 1999 (10.09.99)	11/257035	JP	03 Octo 2000 (03.10.00)
27 Sept 1999 (27.09.99)	11/272391	JP	03 Octo 2000 (03.10.00)
01 June 2000 (01.06.00)	2000/164285	JP	03 Octo 2000 (03.10.00)
01 June 2000 (01.06.00)	2000/164286	JP	03 Octo 2000 (03.10.00)

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer Somsak Thiphrakesone Telephone No. (41-22) 338.83.38

Form PCT/IB/304 (July 1998)

003638114

外国方式

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ E P

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference 662015
International application No. PCT/JP00/04693	International filing date *(day/month/year)* 13. 07. 00	(Earliest) Priority date *(day/month/year)* 16. 07. 99
Title of invention PERMANENT MAGNET SYNCHRONOUS MOTOR		

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
1006, Oaza Kadoma,
Kadoma-shi, Osaka 571-8501
Japan

Telephone No.:

Facsimile No.:

Teleprinter No.:

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MATSUSHITA REFRIGERATION COMPANY
2-5, Takaidahondori 4-chome,
Higashiosaka-shi, Osaka 577-8501
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SASAKI, Kenji
4-36-304-B201, Sengokunishimachi,
Kadoma-shi, Osaka 571-0014
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

[V] Further applicants are indicated on a continuation sheet.

Sheet No. .2.

International application No.
PCT/JP00/04693

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

TAMURA, Teruo
10-8, Mayumi 2-chome,
Ikoma-shi, Nara 630-0122
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

YOSHIDA, Michihiro
19-34-5, Oshiocho,
Takefu-shi, Fukui 915-0863
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

TAKIMOTO, Toru
66-8-9, Shiromarucho,
Takefu-shi, Fukui 915-0857
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

TANIGUCHI, Hideyuki
60-12-2, Katayacho,
Takefu-shi, Fukui 915-0893
Japan

State *(that is, country)* of nationality: Japan	State *(that is, country)* of residence: Japan

[V] Further applicants are indicated on another continuation sheet.

Sheet No. 3.

International application No. PCT/JP00/04693

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

UESAKA, Hiroyuki
66-11-8, Shiromarucho,
Takefu-shi, Fukui 915-0857
Japan

State *(that is, country)* of nationality: Japan

State *(that is, country)* of residence: Japan

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

Sheet No. 4.

International application No.
PCT/JP00/04693

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☐ agent ☑ common representative

and ☐ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☑ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Gill Jennings & Every
Broadgate House
7 Eldon Street
London EC2M 7LH
ENGLAND

Telephone No.: 020-7377-1377

Facsimile No.: 020-7377-1310

Teleprinter No.:

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

☑ the international application as originally filed

the description ☐ as originally filed
☐ as amended under Article 34

the claims ☐ as originally filed
☐ as amended under Article 19 (together with any accompanying statement)
☐ as amended under Article 34

the drawings ☐ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ The applicant wishes the start of the international preliminary examination **to be postponed** until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

☑ which is the language in which the international application was filed.
☐ which is the language of a translation furnished for the purposes of international search.
☐ which is the language of publication of the international application.
☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby **elects all eligible States** *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

Sheet No. .5.

International application No.
PCT/JP00/04693

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendments under Article 34	:	sheets	☐	☐
3. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4. copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5. letter	:	sheets	☐	☐
6. other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. [V] fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ nucleotide and or amino acid sequence listing in computer readable form
6. [V] other *(specify)*: certificate of payment of fee

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

AOYAMA Tamotsu

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

PATENT COOPERATION TREATY

受付
13. 2. 5

From the INTERNATIONAL BUREAU

PCT

To:
AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540-0001
JAPON

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing (day/month/year) 25 January 2001 (25.01.01)		
Applicant's or agent's file reference 662015	**IMPORTANT NOTICE**	
International application No. PCT/JP00/04693	**International filing date** (day/month/year) 13 July 2000 (13.07.00)	**Priority date** (day/month/year) 16 July 1999 (16.07.99)
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al		

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   AE,AG,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CR,CU,CZ,DE,DK,DM,DZ,EA,EE,EP,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,
   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   25 January 2001 (25.01.01) under No. WO 01/06624

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a **demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer J. Zahra Telephone No. (41-22) 338.83.38

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外国方式

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

INFORMATION CONCERNING ELECTED OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

To:

GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH
ROYAUME-UNI

Date of mailing (day/month/year) 30 January 2001 (30.01.01)	
Applicant's or agent's file reference 662015	**IMPORTANT INFORMATION**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/JP00/04693	13 July 2000 (13.07.00)	16 July 1999 (16.07.99)

Applicant
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

   AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
   EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
   National :AU,BG,CA,CN,CZ,DE,IL,KR,MN,NO,NZ,PL,RO,RU,SE,SK,US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

   EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
   OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
   National :AE,AG,AL,AM,AT,AZ,BA,BB,BR,BY,BZ,CH,CR,CU,DK,DM,DZ,EE,ES,FI,GB, GD,GE,GH,GM,HR,HU,ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MW, MX,MZ,PT,SD,SG,SI,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW

3. The applicant is reminded that he must enter the "national phase" **before the expiration of 30 months from the priority date** before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing , if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

   Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

   The entry into the European regional phase is postponed **until 31 months from the priority date** for all States designated for the purposes of obtaining a European patent.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer: Antonia Muller Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH
GRANDE BRETAGNE

DIARIED

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing *(day/month/year)*	22.03.2001
REPLY DUE	**within 3 month(s)** from the above date of mailing

Applicant's or agent's file reference		
662015		
International application No. PCT/JP00/04693	International filing date *(day/month/year)* 13/07/2000	Priority date *(day/month/year)* 16/07/1999
International Patent Classification (IPC) or both national classification and IPC H02K21/46		
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain document cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

   When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

   Also: For an additional opportunity to submit amendments, see Rule 66.4. For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis. For an informal communication with the examiner, see Rule 66.6.

   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 16/11/2001.

Name and mailing address of the international preliminary examining authority:	Authorized officer / Examiner
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Drysdale, N Formalities officer (incl. extension of time limits) Ottaviani, P Telephone No. +49 89 2399 2225

Form PCT/IPEA/408 (cover sheet) (January 1994)

I. Basis of the opinion

1. This opinion has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".)*:

Description, pages:

1-63 as originally filed

Claims, No.:

1-26 as originally filed

Drawings, sheets:

1/20-20/20 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrialapplicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims
Inventive step (IS)	Claims
Industrial applicability (IA)	Claims

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

V. Reasoned statement

2. Citations and explanations

1. Reference is made to the following documents cited in the international search report:

   D1 = US 5 097 166.

2. Out of a total of 26 claims, the present application includes 11 independent claims in the same category, viz.
   Nos. 1, 3, 5, 10, 11, 14, 17, 18, 23, 24, 25.

   Although these claims have been drafted as separate independent claims, several groups appear to relate effectively to the same subject-matter, the individual claims differing from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

   Hence, the claims now on file do not meet the requirements of Article 6 PCT.

   In order to overcome this objection, it would appear appropriate to file an amended set of claims defining the relevant subject-matter in terms of a minimum number of independent claims in each category followed by dependent claims covering features which are merely optional (Rule 6.4 PCT).

3. In view of the above objection it is not at present possible to carry out a proper substantive examination. However, it appears that the most relevant available document is D1, and that it provides no basis for objection to the claims on file on grounds of lack of novelty or inventive step. This conclusion is, however, provisional.

4. The applicant is invited to file new claims which take account of the comments in the present written opinion.

   When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially of the introductory portion and any statements of problem or advantage, not to add subject-matter which extends beyond the content of the application as originally filed (Article 34(2)(b) PCT).

   In order to facilitate the examination of the conformity of the amended application with the requirements of Article 34(2)(b) PCT, the applicant is requested to clearly identify the amendments carried out, no matter whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see also Rule 66.8(a) PCT). If the applicant regards it as appropriate these indications could be submitted in handwritten form on a copy of the relevant parts of the application as filed.

   The applicant is requested to file amendments by way of replacement pages in the manner stipulated by Rule 66.8(a) PCT. In particular, fair copies of the amendments should be filed preferably in triplicate.

   Moreover, the applicant's attention is drawn to the fact that, as a consequence of Rule 66.8(a) PCT the examiner is not permitted to carry out any amendments under the PCT procedure, however minor these may be.

VII. Certain defects

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

VIII. Certain observations

1. The claims are not clear in several respects (Art. 6 PCT). In several claims reference is made to slots for conductor bars, slots for permanent magnets and "slots". In most, if not all, cases it appears that the "slots" are conductor bar slots, and this should be made clear.

2. The second paragraphs of claims 6 and 7 appear to be redundant, as they are already included in claim 5, on which these claims depend.

3. Claim 5 concerns details of the short-circuit rings. However, these details, apparently shown in Fig. 17, appear to be made necessary by the arrangement of the permanent magnets shown in Fig. 15 (cf. description, page 33, line 11 to page 34, line 6), yet this arrangement is not described in claim 5. Independent claim 5 does not, therefore, appear to include all the essential technical features necessary to define the invention (Art. 6 PCT).

4. It is not clear what, if any, is the difference between the "third embodiment" (page 29, Fig. 4) and the "fourth embodiment" (Fig. 5, page 30).

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)* 21.08.2001		
Applicant's or agent's file reference 662015	**IMPORTANT NOTIFICATION**	
International application No. PCT/JP00/04693	International filing date *(day/month/year)* 13/07/2000	Priority date *(day/month/year)* 16/07/1999
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Looijen, H Tel.+49 89 2399-2613

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 662015	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/JP00/04693	International filing date *(day/month/year)* 13/07/2000	Priority date *(day/month/year)* 16/07/1999
International Patent Classification (IPC) or national classification and IPC H02K21/46		
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand 07/12/2000	Date of completion of this report 21.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Drysdale, N Telephone No. +49 89 2399 2435

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
   Description, pages:

   1-63 as originally filed

   Claims, No.:

   1-26 as originally filed

   Drawings, sheets:

   1/20-20/20 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-26
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-26
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-26
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

V. **Reasoned statement**

2. **Citations and explanations**

1. Reference is made to the following documents cited in the international search report:

   D1 = US 5 097 166.

2. Out of a total of 26 claims, the present application includes 11 independent claims in the same category, viz.
   Nos. 1, 3, 5, 10, 11, 14, 17, 18, 23, 24, 25.

   Although these claims have been drafted as separate independent claims, several groups appear to relate effectively to the same subject-matter, the individual claims differing from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

   Hence, the claims now on file do not meet the requirements of Article 6 PCT.

   In order to overcome this objection, it would have been appropriate to file an amended set of claims defining the relevant subject-matter in terms of a minimum number of independent claims in each category followed by dependent claims covering features which are merely optional (Rule 6.4 PCT).

3. In view of the above objection it is not at present possible to carry out a proper substantive examination. However, it appears that the most relevant available document is D1, and that it provides no basis for objection to the claims on file on grounds of lack of novelty or inventive step. This conclusion is, however, provisional.

VII. Certain defects

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

VIII. Certain observations

1. The claims are not clear in several respects (Art. 6 PCT). In several claims reference is made to slots for conductor bars, slots for permanent magnets and "slots". In most, if not all, cases it appears that the "slots" are conductor bar slots, and this should be made clear.

2. The second paragraphs of claims 6 and 7 appear to be redundant, as they are already included in claim 5, on which these claims depend.

3. Claim 5 concerns details of the short-circuit rings. However, these details, apparently shown in Fig. 17, appear to be made necessary by the arrangement of the permanent magnets shown in Fig. 15 (cf. description, page 33, line 11 to page 34, line 6), yet this arrangement is not described in claim 5. Independent claim 5 does not, therefore, appear to include all the essential technical features necessary to define the invention (Art. 6 PCT).

4. It is not clear what, if any, is the difference between the "third embodiment" (page 29, Fig. 4) and the "fourth embodiment" (Fig. 5, page 30).

PCT REQUEST

Original (for **SUBMISSION**) - printed on 12.07.2000 03:36:14 PM

0 0-1	**For receiving Office use only** International Application No.	
0-2	International Filing Date	PCT 13.7.00 受領印
0-3	Name of receiving Office and "PCT International Application"	
0-4 0-4-1	**Form - PCT/RO/101 PCT Request** Prepared using	PCT-EASY Version 2.91 (updated 01.07.2000)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	Japanese Patent Office (RO/JP)
0-7	**Applicant's or agent's file reference**	662015
I	**Title of invention**	PERMANENT MAGNET SYNCHRONOUS MOTOR
II	**Applicant**	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
II-5	Address:	1006, Oaza Kadoma, Kadoma-shi, Osaka 571-8501 Japan
II-6	State of nationality	JP
II-7	State of residence	JP
III-1	**Applicant and/or inventor**	
III-1-1	This person is:	applicant only
III-1-2	Applicant for	all designated States except US
III-1-4	Name	MATSUSHITA REFRIGERATION COMPANY
III-1-5	Address:	2-5, Takaidahondori 4-chome, Higashiosaka-shi, Osaka 577-8501 Japan
III-1-6	State of nationality	JP
III-1-7	State of residence	JP

III-2	**Applicant and/or inventor**	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	SASAKI, Kenji
III-2-5	Address:	4-36-304-B201, Sengokunishimachi, Kadoma-shi, Osaka 571-0014 Japan
III-2-6	State of nationality	JP
III-2-7	State of residence	JP
III-3	**Applicant and/or inventor**	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	TAMURA, Teruo
III-3-5	Address:	10-8, Mayumi 2-chome, Ikoma-shi, Nara 630-0122 Japan
III-3-6	State of nationality	JP
III-3-7	State of residence	JP
III-4	**Applicant and/or inventor**	
III-4-1	This person is:	applicant and inventor
III-4-2	Applicant for	US only
III-4-4	Name (LAST, First)	YOSHIDA, Michihiro
III-4-5	Address:	19-34-5, Oshiocho, Takefu-shi, Fukui 915-0863 Japan
III-4-6	State of nationality	JP
III-4-7	State of residence	JP
III-5	**Applicant and/or inventor**	
III-5-1	This person is:	applicant and inventor
III-5-2	Applicant for	US only
III-5-4	Name (LAST, First)	TAKIMOTO, Toru
III-5-5	Address:	66-8-9, Shiromarucho, Takefu-shi, Fukui 915-0857 Japan
III-5-6	State of nationality	JP
III-5-7	State of residence	JP
III-6	**Applicant and/or inventor**	
III-6-1	This person is:	applicant and inventor
III-6-2	Applicant for	US only
III-6-4	Name (LAST, First)	TANIGUCHI, Hideyuki
III-6-5	Address:	60-12-2, Katayacho, Takefu-shi, Fukui 915-0893 Japan
III-6-6	State of nationality	JP
III-6-7	State of residence	JP

PCT REQUEST

662015

Original (for SUBMISSION) - printed on 12.07.2000 03:36:14 PM

III-7	**Applicant and/or inventor**	
III-7-1	This person is:	applicant and inventor
III-7-2	Applicant for	US only
III-7-4	Name (LAST, First)	UESAKA, Hiroyuki
III-7-5	Address:	66-11-8, Shiromarucho, Takefu-shi, Fukui 915-0857 Japan
III-7-6	State of nationality	JP
III-7-7	State of residence	JP
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	AOYAMA, Tamotsu
IV-1-2	Address:	AOYAMA & PARTNERS IMP Building, 3-7, Shiromi 1-chome, Chuo-ku,Osaka-shi, Osaka 540-0001 Japan
IV-1-3	Telephone No.	06-6949-1261
IV-1-4	Facsimile No.	06-6949-0361
IV-2	**Additional agent(s)**	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	KAWAMIYA, Osamu; ISHINO, Masahiro
V	**Designation of States**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AP: GH GM KE LS MW MZ SD SL SZ TZ UG ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT OA: BF BJ CF CG CI CM GA GN GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH&LI CN CR CU CZ DE DK DM DZ EE ES FI GB GD GE GH GM HR HU ID IL IN IS KE KG KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW

V-5	**Precautionary Designation Statement** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	**Exclusion(s) from precautionary designations**	NONE
VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	16 July 1999 (16.07.1999)
VI-1-2	Number	Patent Application No.11-203080
VI-1-3	Country	JP
VI-2	**Priority claim of earlier national application**	
VI-2-1	Filing date	16 July 1999 (16.07.1999)
VI-2-2	Number	Patent Application No.11-203081
VI-2-3	Country	JP
VI-3	**Priority claim of earlier national application**	
VI-3-1	Filing date	10 September 1999 (10.09.1999)
VI-3-2	Number	Patent Application No.11-257035
VI-3-3	Country	JP
VI-4	**Priority claim of earlier national application**	
VI-4-1	Filing date	27 September 1999 (27.09.1999)
VI-4-2	Number	Patent Applicaiton No.11-272391
VI-4-3	Country	JP
VI-5	**Priority claim of earlier national application**	
VI-5-1	Filing date	01 June 2000 (01.06.2000)
VI-5-2	Number	Patent Application No.2000-164285
VI-5-3	Country	JP
VI-6	**Priority claim of earlier national application**	
VI-6-1	Filing date	01 June 2000 (01.06.2000)
VI-6-2	Number	Patent Application No.2000-164286
VI-6-3	Country	JP
VII-1	**International Searching Authority Chosen**	European Patent Office (EPO) (ISA/EP)

VIII	Check list	number of sheets	electronic file(s) attached
VIII-1	Request	5	–
VIII-2	Description	63	–
VIII-3	Claims	10	–
VIII-4	Abstract	1	662015.txt
VIII-5	Drawings	20	–
VIII-7	TOTAL	99	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	–
VIII-10	Copy of general power of attorney	✓	–
VIII-16	PCT-EASY diskette	–	diskette
VIII-18	**Figure of the drawings which should accompany the abstract**	1	
VIII-19	**Language of filing of the international application**	English	
IX-1	**Signature of applicant or agent**		
IX-1-1	Name (LAST, First)	AOYAMA, Tamotsu	

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10-1	**Date of actual receipt of the purported international application**	
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/EP
10-6	**Transmittal of search copy delayed until search fee is paid**	

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11-1	**Date of receipt of the record copy by the International Bureau**	

PATENT COOPERATION TREA

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 662015	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/JP 00/04693	International filing date *(day/month/year)* 13/07/2000	(Earliest) Priority Date *(day/month/year)* 16/07/1999
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/04693

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02K21/46 H02K1/27

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1 552 694 A (CEM COMP ELECTRO MEC) 19 September 1979 (1979-09-19) figure 1 ---	
A	CH 458 510 A (SIEMENS AG) 30 August 1968 (1968-08-30) figures 2,3 ---	
A	US 4 322 648 A (RAY GLEN ET AL) 30 March 1982 (1982-03-30) column 3, line 46 -column 3, line 60 ---	
A	US 5 097 166 A (MIKULIC KRESO) 17 March 1992 (1992-03-17) figure 4 --- -/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 2000	06/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ramos, H

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International Application No
PCT/JP 00/04693

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 352 573 A (SIEMENS AG) 31 January 1990 (1990-01-31) figure 3 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP 00/04693

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 1552694 A	19-09-1979	FR 2324150 A	08-04-1977
		CH 607432 A	15-12-1978
		DE 2621301 A	09-12-1976
		IT 1063215 B	11-02-1985
CH 458510 A		NONE	
US 4322648 A	30-03-1982	CA 1135761 A	16-11-1982
US 5097166 A	17-03-1992	CA 2051752 A,C	25-03-1992
EP 0352573 A	31-01-1990	JP 2079737 A	20-03-1990
		US 4922152 A	01-05-1990